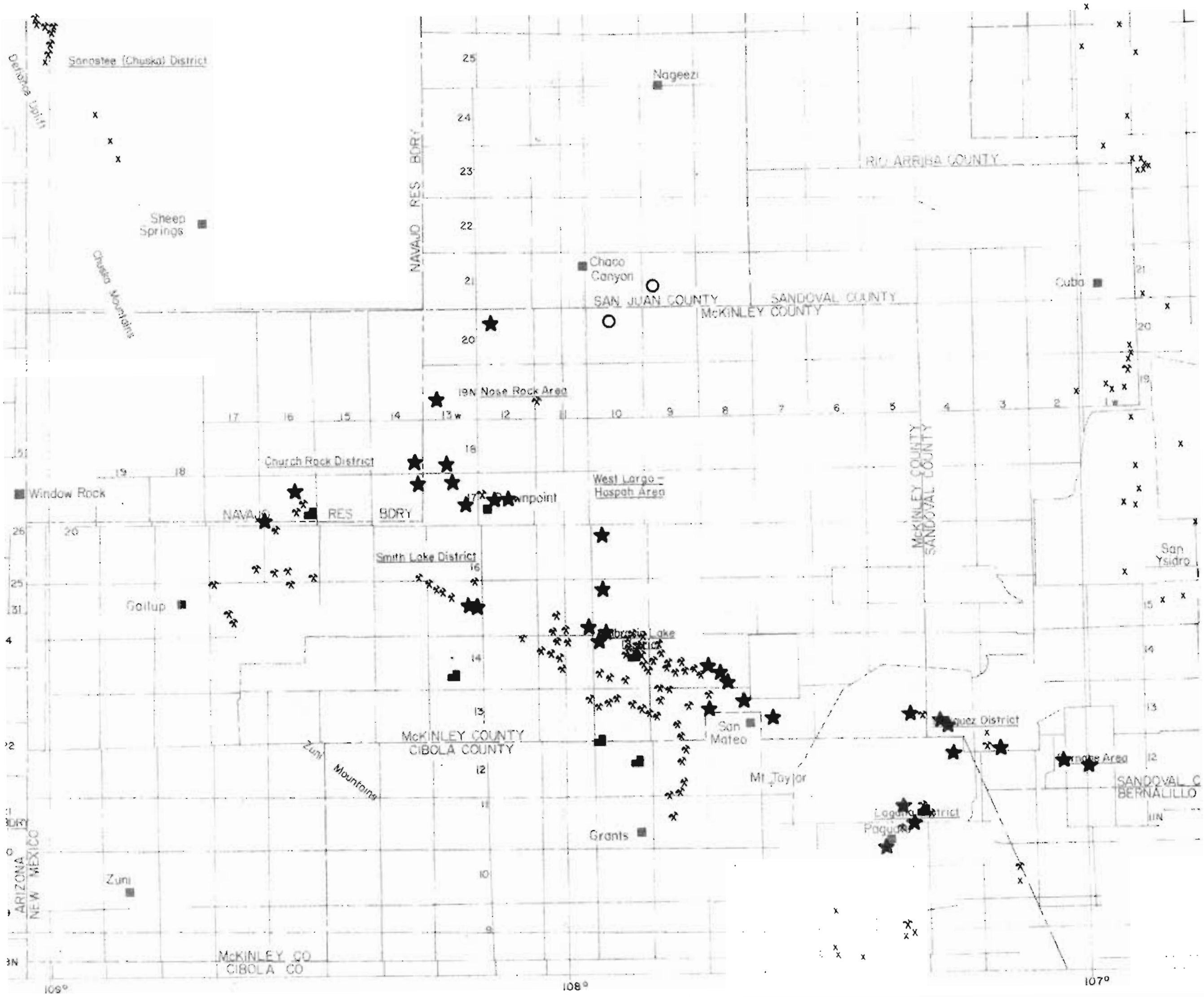
Uranium Resources and Technology

A Review of the New Mexico Uranium Industry 1980



New Mexico Energy and Minerals Department

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NOTICE

Uranium Resources and Technology

A Review of the New Mexico Uranium Industry

1980

New Mexico Energy and Minerals Department
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URANIUM RESOURCES and TECHNOLOGY

- a review of the New Mexico uranium industry 1980

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PREFACE

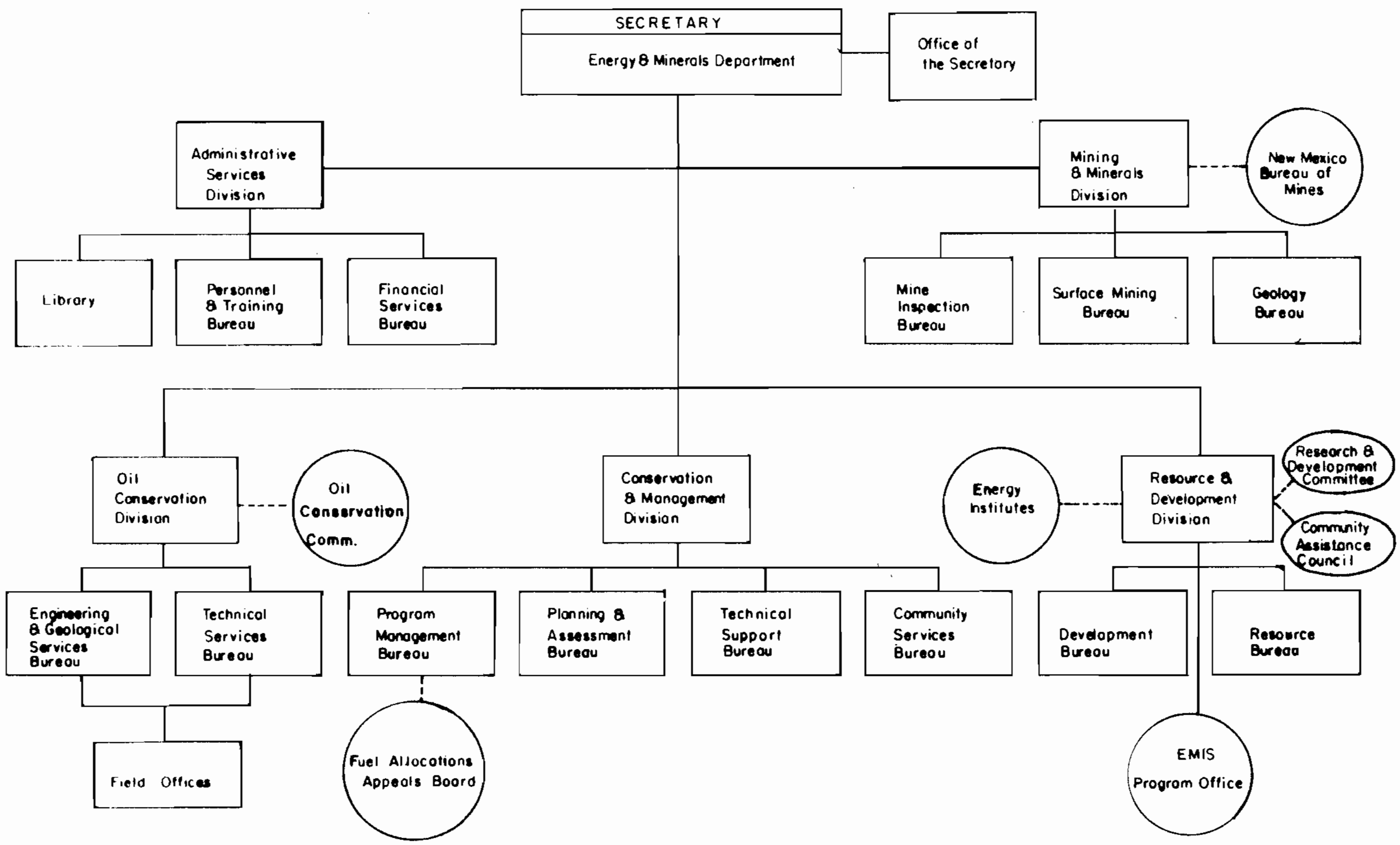
The Energy Resources Board was created on July 1, 1975, pursuant to Chapter 289 of the Laws of 1975. The Office of State Geologist was established at that time, and it is from that office that the present Bureau of Geology evolved. One of three bureaus under the newly established Mining and Minerals Division of the Energy and Minerals Department, the Bureau of Geology was created under the Energy and Minerals Department Act, Chapter 255 of the Laws of 1977 which became effective on March 31, 1978. The Bureau is charged with the responsibility of conducting within the state, geological studies of known, probable and potential supplies of natural sources of energy with the aim of determining their reserves and life expectancy. These energy sources include fossil fuels, radioactive minerals and geothermal energy. The Bureau is also directed to cooperate with the New Mexico Bureau of Mines and Mineral Resources in preparing maps, brochures and pamphlets of known, probable and potential sources of energy in New Mexico; to cooperate with private, state and federal agencies in the gathering of geological data concerning energy supplies, and assisting the Secretary of the Energy and Minerals Department in the maintenance of an inventory of all reserves and potential sources of fuel and power in New Mexico.

The Energy Resource and Development Division also began as a divison of the Energy Resources Board. Under the Energy Resources Board, the Division was assigned the responsibility of helping prepare and administer the state energy management program.

Within the present Energy and Minerals Department, which replaced the Energy Resources Board, the Energy Resources and Development Division was created pursuant to Section 957 NMSA 1978 (on July 1, 1978). The statute gave the Division two mandates: (1) develop, implement and administer energy impact programs which effect the state and its political subdivisions; and (2) monitor energy development in the state in cooperation with state and federal agencies, political subdivisions and private industry so that benefits to the state can be maximized.

The Bureau of Geology under the Mining and Minerals Division and the Resource and Development Division have cooperated in the implementation of a comprehensive uranium program which monitors all aspects and implications of the uranium extracting and processing industry in the state.

ORGANIZATION CHART OF NEW MEXICO ENERGY AND MINERALS DEPARTMENT



A C K N O W L E D G E M E N T S

The New Mexico Energy and Minerals Department (EMD) wishes to express appreciation to the contributors of this report; first to Bill Hatchell of the Mining and Minerals Division and to Chris Wentz of the Resources and Development Division for their effort in compiling the report from its many sources. The five authors who willingly donated their professional experience and knowledge of the industry include Bill Chenoweth, Staff Geologist of the U.S. Department of Energy; Emily Miller and Chris Wentz, Energy Consultants with the Resource and Development Division of EMD; Bill Hatchell, Uranium Geologist with the Mining and Minerals Division of EMD; and Betty Perkins, Energy Consultant to EMD. Mr. Bob Jebb of Solo Writing and Editing in Santa Fe provided editorial assistance in addition to the EMD staff. Mrs. Anne Gariss of A. G. Drafting in Albuquerque was responsible for all original illustrations, and Ginger Maes, Sandy Trujillo, Joanne Lamoreux and Ada Espinosa-Lujan of EMD provided continual clerical and typing support.

The Technical support of the U.S. Department of Energy (DOE) in Grand Junction and Albuquerque was invaluable both in the formative stages of the report as well as in the final editing and correcting of the draft report. EMD would like to thank Bill Chenoweth, Harlen Holen and Jim Olsen of DOE in particular for their generous contribution of time and knowledge.

It would be impossible to mention everyone in the uranium industry who kindly provided their cooperation, criticisms and suggestions to EMD during the course of field and office visits. Their contributions are genuinely appreciated, however, and without their help the report would not have been possible. The comments of Mr. Lynn Jacobsen, private uranium consultant and geologist, were of particular value following the release of the draft report.

The assistance and input from several state agencies should also be acknowledged; these include the Environmental Improvement Division (EID) of the New Mexico Health and Environment Department; the New Mexico Taxation and Revenue Department; the Minerals Division of the State Land Office; the Bureau of Mine Inspection within the Mining and Minerals Division of EMD; the Water Resources Division of the Natural Resources Department and last but not least Inter-Agency Services, for their collating, printing and binding services.

Finally, the encouragement and administrative support of several individuals in EMD must be acknowledged; these include Larry Kehoe, Secretary; Charles Turpen, Deputy Secretary; Emery Arnold, Director of the Mining and Minerals Division; Jim Hill, Chief of the Bureau of Geology; George Scudella, Chief of the Resources Bureau; and Pat Rodriguez, Director of the Resource and Development Division.

INTRODUCTION

New Mexico's uranium industry is experiencing a deep-seated and serious depression, a decline that was significantly affected by the Three Mile Island nuclear reactor accident in Pennsylvania in 1979, that sent spot market prices for uranium tumbling from a high of over $43.00 per lb to less than $30.00 per lb in one year. To add to the woes of the state's uranium industry, a mill tailings pond embankment accidently collapsed that same year at Church Rock and allowed millions of gallons of contaminated water to flood down the Rio Puerco of the West across the Navajo Reservation and into Arizona. Repercussions of these two events are still being felt.

Since these two major events, at least 16 mines have closed, including several older operations that have been in production since the 1950's, and two newer mines that had been in operation for less that 2 years. By late 1980, approximately 10 percent of the state's uranium mine production capacity had been lost through mine closures and more than 1800 miners and support personnel had been terminated.

The nuclear industry throughout the United States is at a standstill. No new reactors have been ordered; several plants that were approved, planned or under construction have been cancelled or delayed; and an over-supply of uranium has kept market prices depressed with delivery commitments being filled from oversupply stockpiles rather than through production. The nation has no clear-cut nuclear energy program nor an effective program for nuclear waste disposal.

In the meantime, problems of a more local nature have continued to complicate exploration, new mine development and production within the state's boundaries. Public lack of acceptance has been a major factor, especially near and within the boundaries of the Navajo Reservation, on public lands, and within the domain of environmentally sensitive national forest lands. Planned exploration projects have been aborted or delayed indefinitely; law suits have been filed against uranium operators, and mill and tailings disposal licenses have been delayed beyond traditionally acceptable periods. Several mine development projects already underway may be unable to meet first production deadlines as stipulated in their leases, and some have been delayed indefinitely or cancelled altogether.

Severance taxes on uranium, the state's largest mining industry in terms of employees, payroll, product value, and revenues generated, were recently increased to a level which industry complains is unfair and ill-timed. Industry argues that New Mexico's severance tax on uranium is now the highest in the nation and that producers have found the development and production of uranium in New Mexico to be less attractive than in other areas where production costs and taxes are lower. The rationale behind increased severance tax was based on the relative health of the industry in 1977, 1978, and 1979 when uranium market prices were at an all-time high and many new mines were under development or planned. New Mexico is still the nation's number one producer of this energy metal but production has declined more noticeably than in Wyoming and Texas and the future is uncertain. In addition, New Mexico stands to lose much of its lower cost reserves through excessive overall production costs compared to other areas.

Data for the precursor of this report, "An Overview of the New Mexico Uranium Industry," was gathered in late 1978 and published in January 1979, just before the impact of the chain of events that began at Three Mile Island. The health of the New Mexico uranium industry was then robust with optimistic prospects for the future. The Grants Mineral Belt had been extended to depths in excess of 3,000 ft and to a distance of 10 to 15 miles northward from its former boundary. Today, the industry is depressed and uncertain of its future role. This report is an expansion of "An Overview of the New Mexico Uranium Industry." It is an attempt to present an accurate and unbiased picture of the industry in terms of a historical review, current conditions, and projections for the future of the industry. The original report has been modified in several areas, including the addition of chapters dealing with environmental and socio-economic impacts. Geologic descriptions of uranium occurences include not only those of the Grants Minerals Belt, but those of the entire state. Technical aspects of both mining and milling are reviewed in detail. Production economics are summarized, but not discussed in depth. Much of the statistical data is current through December, 1980. In addition, the glossary of technical terms has been expanded, and for the first time, a regulatory chart has been included which identifies state and federal agencies that regulate specific aspects of the front-end of the nuclear cycle from exploration to mill tailings disposal.

The Energy and Minerals Department expects to update this review of the New Mexico uranium industry as important changes in technology, economics and regulatory policy occur. It is hoped that the document will serve as a comprehensive review and guide to the state's largest mining industry.

CHAPTER I

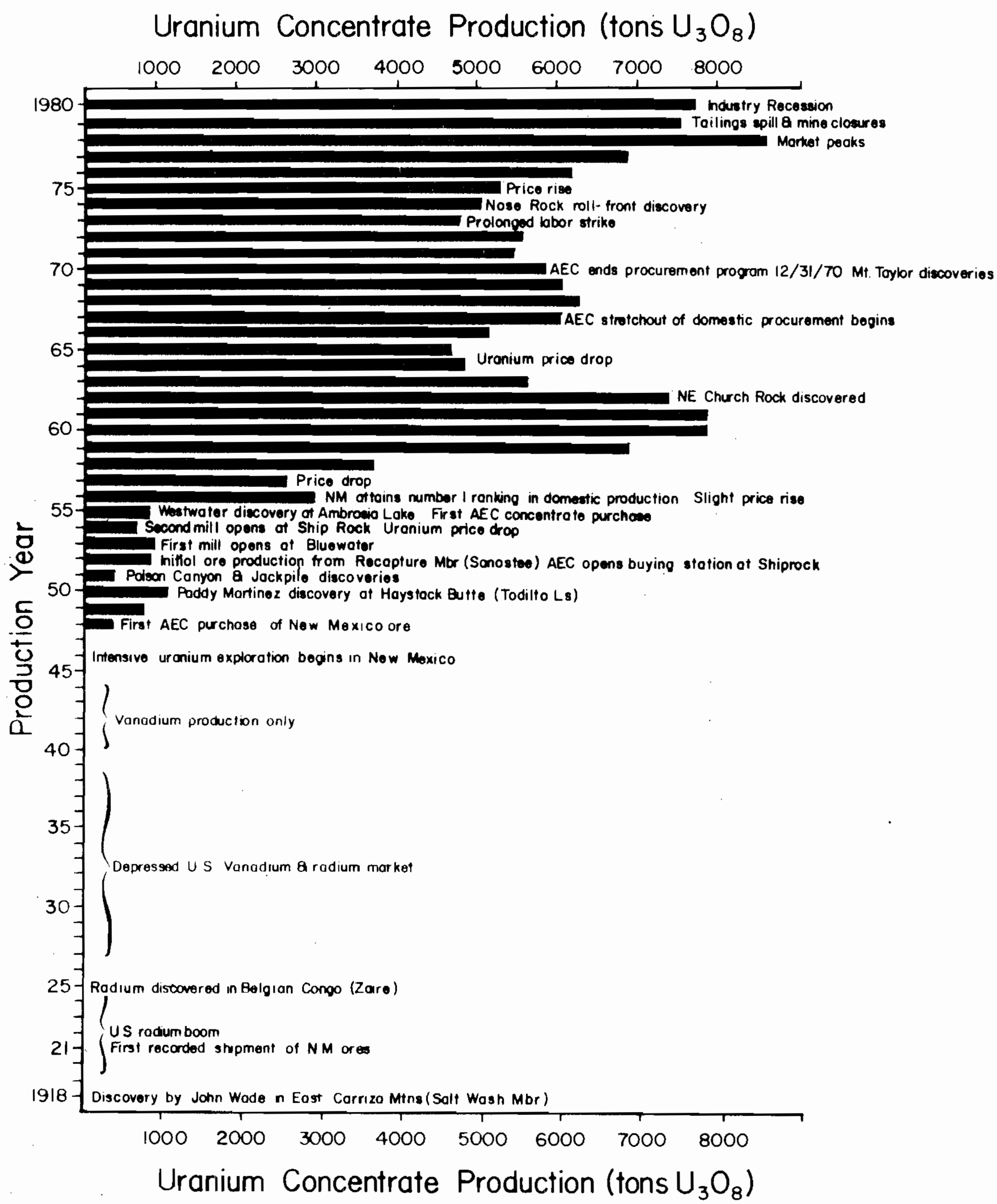
HISTORY OF NEW MEXICO URANIUM INDUSTRY

According to historical information obtained by the U.S. Department of Energy, the discovery of uranium in New Mexico must be credited to a prospector by the name of John Wade in the East Carrizo or Shiprock area of the Navajo Indian Reservation (Chenoweth and Learned, 1980). Wade recognized carnotite ores in outcrops of the Salt Wash Member of the Jurassic Morrison Formation in 1918 and subsequently leased several thousand acres of claims astride the New Mexico-Arizona border near Milepost 16 in San Juan County. The Carriso (sic) Mining Company was formed by Wade to develop the property although not for mining the uranium contained in the ores, but for the associated vanadium and rare element radium. Unfortunately, no records exist to corroborate the production from the Wade claims prior to 1921, when a shipment of several gunnysacks of ore were shipped for the extraction of radium. However, in a report by Staver (1921), it was noted that high grade ore was stored at Beclabito Trading Post before shipment to Colorado (Chenoweth and Learned, 1980). Thus, the Wade discovery led to the first apparent shipment and production of uraniferous ores from New Mexico. (Figure I-1)

One year after Wade's discovery, radium was discovered in southwestern New Mexico in the White Signal district in Grant County where several mines were located including the Merry Widow, the Floyd Collins, and the Eugenie (Lovering, 1956). The discovery of rich pitchblende deposits at Shinkolobwe, Leopoldville in the Belgian Congo in 1925, however, had a devastating effect on the U.S. radium market. Sufficient demand for U.S. vanadium did not actually develop until after 1940.

As a result of World War II, the Vanadium Corporation of America (VCA) sought to meet an increasing demand for metallurgical vanadium by leasing and mining the various East Carrizo claim blocks between 1941 and 1944. VCA mined the vanadium ores which were purchased by Metals Reserve Company, an agent formed by the federal government to secure adequate domestic supplies of the metal for the war armaments program. VCA operated a mill at Monticello, Utah for Metals Reserve, where the East Carrizo ores were processed. Vanadium pro-

Figure I-1. History of uranium, radium and vanadium discovery and production in New Mexico from 1918 to 1979 showing important milestones in the state's uranium industry (data compiled from the U.S. Department of Energy, 1980a).



duction ceased in 1944 when the war armaments program was terminated.

The atomic energy program was begun in the United States in 1942 with the inception of the Manhattan Project. As part of a concerted effort by the federal government to assess the nation's uranium resources and to assure a reliable supply of the strategic metal, the Union Mines Development Corporation (UMDC) was formed in 1943 as part of the Manhattan Project. In order to fulfill the objective of recommending acquisition of uranium resource areas by the government, UMDC geologists began in intensive exploration program. Areas of known occurrences of radioactive minerals were studied including those in the White Signal and East Carrizo districts of New Mexico. (Coleman, 1944). East Carrizo ores accounted for virtually all of New Mexico uranium production between 1948 and 1953, but since all ores were shipped to the VCA mill in Durango, Colorado, the state was not credited with uranium production until 1953 . (W.L. Chenoweth, personal communication, August 1980). Concentrate purchases from New Mexico by the Atomic Energy Commission did not begin until 1953. Between 1944 and 1947 there was no production reported from the Carrizo Mountain area.

After the inception of the U. S. Atomic Energy Commission (AEC) in 1947, uranium exploration and ore production was further stimulated by the Federal Government. As early as 1951, AEC reconnaissance parties studied the geology of the state in order to delineate commercially viable uranium deposits. During early 1952, the King Tutt Mesa area of the East Carrizos became the focus of AEC exploration efforts with an initial diamond drilling program in combination with airborne radiometric surveys (Blagbrough and Brown, 1955). The Sanostee area south of the East Carrizos was first mapped by the AEC in late 1953 after ore discoveries in the Recapture Member of the Morrison Formation increased interest in that area (Blagbrough and others, 1955). An account of the geologic studies by UMDC is available in the report by Coleman (1944). The East Carrizo area subsequently became a model for the testing of stratigraphic exploration techniques pioneered by the petroleum industry. Gamma logging was restricted to hand-operated geiger probes, as no gamma log technology had been developed. Drill cores were taken, however, and stratigraphic analyses using sandstone/mudstone ratios, isopaching and structural contouring were utilized to assess the subsurface uranium geology.

Meanwhile, all New Mexico uranium production from sandstones was shipped to the VCA mill at Durango, Colorado, until 1954 when Kerr-McGee Oil Industries opened the state's first acid-leach mill at Shiprock (Masters and others, 1955).

Economic deposits of uranium in the Grants area were not discovered until the spring of 1950 when a Navajo sheepherder by the name of Paddy Martinez noticed a colorful mineralized outcrop of Todilto Limestone at the base of Haystack Butte near Prewitt. The mineral was identified as tyuyamunite, a calcium-uranium vanadate, and the discovery subsequently spawned the establishment of the Haystack Mountain Development Company, a mining subsidiary of the Santa Fe Pacific Railway. Shortly thereafter, open-pit uranium mines dotted the Todilto bench around Haystack Butte and the surrounding area and many companies including the Anaconda Company joined in New Mexico's second uranium rush. The first shipment of Todilto ore was made in December, 1950 to the A.E.C. buying station at Monticello, Utah.

By mid-1953, the state's first alkaline-leach mill was operating at Bluewater, built by Anaconda in order to process the Todilto limestone ores. It should be noted that the Bluewater mill was also New Mexico's first mill, predating the Shiprock facility of Kerr-McGee by one year. A second mill was soon constructed to treat the sandstone ores which were developed after the initial discovery of uranium in the Morrison Formation (Poison Canyon) in early 1951 and subsequent Morrison (Jackpile) discoveries at Laguna in the fall of 1951. By 1954, the Jackpile-Paguate mine had become the largest uranium mine in the United States. In the Gallup area, mineralization was detected in the Dakota Sandstone where mines were also developed.

Drilling downdip from the initial outcrop discoveries led to the delineation of the famous Poison Canyon trend at Ambrosia Lake. Uranium mineralization was not recognized in the Westwater Canyon Sandstone Member of the Morrison until 1955 when a wildcat drill hole intercepted a mineralized zone at a depth slightly in excess of 300 ft at Ambrosia Lake which led to the eventual discovery of the large Westwater subsurface deposits that, along with the extensive Jackpile-Paguate deposit at Laguna, thrusted New Mexico into the forefront as the nation's leading uranium producer. By 1957, four mills were under construction in the Ambrosia Lake area with a total capacity of over 7,200 tons per day (File and Northrop, 1966). Uranium production was reported from eleven counties throughout the state with McKinley and Valencia counties contributing the bulk of production.

When the U. S. Government curtailed its uranium procurement program in

1967 and finally ceased purchases by the end of 1970, an expanding electrical utility industry began to affect the uranium market, and demand gradually boosted the price of the energy metal to more than $40/lb. A new surge of exploration and development once again stimulated the New Mexico uranium industry. Larger and deeper mineralized trends were found down-dip from the earlier deposits.

Even after the Ambrosia Lake/Smith Lake subsurface discoveries, exploration efforts had been directed basinward across the Chaco slope. The Churchrock orebodies were discovered in 1965 by the Kerr-McGee Corporation at depths exceeding 1800 ft, and in the early 1970's strongly mineralized zones in the Westwater at depths exceeding 2000 ft had been intercepted by Mobil, Conoco, and United Nuclear in the Dalton Pass-Crownpoint area. By late 1974, Phillips Petroleum had recognized a unique type of uranium deposit in the Westwater Member at depths of 2600 ft or more near Seven Lakes northeast of Crownpoint. The development, named Nose Rock after a locally prominent landform, was to become New Mexico's first major roll-type uranium deposit where roll-front geochemistry and morphology, developed earlier in Wyoming and used successfully as an exploration concept in Texas, were used almost exclusively as ore guides during the exploration drilling phase of the project.

As early as 1970, Bokum Resources had made a significant uranium discovery on the northwestern slope of Mount Taylor at depths of 3300 ft. The deposit, developed by Gulf, was to become the deepest and largest uranium mining operation in North America, and extended the Ambrosia Lake mining district several miles further east beneath the flanks of Mount Taylor, an 11,000 foot volcano of Tertiary age.

Further east, De Villiers Nuclear had discovered Westwater mineralization in the Marquez area on the eastern slope of Mount Taylor at depths of 2100 ft. The orebody was subsequently purchased by Bokum Resources. All known mineralization in the area had been in the Brushy Basin (Jackpile) prior to the De Villiers discovery. In early 1971, Conoco extended the known Grants Mineral Belt to its easternmost limit with the discovery of a complex of Westwater deposits on the Bernabe Montano Grant 40 miles east of Ambrosia Lake in the Laguna district.

Although uranium exploration and mining have suffered a decline since 1978, several large mining developments in the Crownpoint, Mount Taylor and Laguna-Marquez areas continue to make progress, and land acquisition and exploration activities are continuing to emphasize the exploration of lateral extensions of these recently discovered trends as well as certain outlying frontier areas both within and beyond the bounds of the San Juan Basin. A detailed history of exploration in the Grants uranium region since 1963 is presented by Chenoweth and Holen (1980).

Uranium deposits have been delineated in the Chama Embayment on the east side of the San Juan Basin, as well as in the Quemado-Datil area to the south, and exploration efforts are still in progress on Navajo Tribal leases near Sanostee in the northwestern part of the state. Low-grade mineralization has been discovered and delineated in the Hagan Basin near Cerrillos and on Mesa Portales near Cuba. Interest has been shown in exploring for uranium near Tres Piedres in Rio Arriba County, and some wildcat drilling has been reported near Socorro and Lordsburg.

Uncertainties concerning the future, however, continue to plague the New Mexico uranium industry. Several factors have contributed to this uncertainty including depressed market prices, expensive and time-consuming regulatory requirements, and purely technical and economic considerations of ever deeper and lower-grade deposits. In spite of these uncertainties, New Mexico continues to lead the nation in total recoverable reserves as well as total annual production. Only Wyoming has ever approached or exceeded New Mexico in total yearly production. A comparison of the Grants mineral region as the premier mining district of the world with other domestic and foreign uranium deposits is presented by Robert J. Wright (1980).

CHAPTER II

GEOLOGY OF NEW MEXICO URANIUM DEPOSITS & OCCURRENCES

Geologic Setting

Uranium occurs in all of the four physiographic provinces that comprise the State of New Mexico, including the Colorado Plateau, the Southern Rocky Mountains, the Basin-Range, and the Great Plains (Figure II-1). Host rocks range in age from Precambrian to Quaternary and include plutonic rocks and their associated pegmatitic veins and metamorphics, volcanic and sedimentary rocks, (Table II-1). The bulk of all occurrences of current economic interest are epigenic sandstone and limestone deposits on the Colorado Plateau of northwestern New Mexico.

Colorado Plateau Deposits

The Colorado Plateau occupies approximately all of the northwestern quadrant of the state. Two structural elements within the New Mexico portion of the plateau that are important hosts for uranium occurrences are the San Juan Basin in the northern area and the East Mogollon slope in the southern area of the plateau (Figure II-2).

The San Juan Basin is the largest and most important physiographic and structural element. Roughly circular in plan and centered near the Rio Arriba-San Juan County line, the basin contains the largest and most prolific uranium deposits known in the United States (Figure II-3). Since more than 50 percent of the nation's uranium reserves are located there, the basin should continue to be an important exploration and production area. More than 14,000 ft of Paleozoic, Mesozoic, and Cenozoic sedimentary deposits are buried beneath the deepest part of the basin. They dip gently inward and crop out concentrically with the older rocks exposed around the basin margins and the younger rocks toward the center. The stratigraphic sequence is intruded by and capped with volcanic rocks of late Tertiary and Quaternary ages (i.e., Mount Taylor volcanic field and Shiprock). Folding and faulting, in general, are less severe than in areas that surround the plateau such as the Basin-Range and Rocky Mountain provinces. Various depressions and uplifts surround the basin itself. On the north is the San Juan Uplift, mostly in Colorado. Moving southeastward, the San Juan Uplift merges with the Brazos-Tusas high-

Figure II-1. Physiographic provinces and tectonic elements favorable for the occurrence of uranium in New Mexico (New Mexico Bureau of Geology).

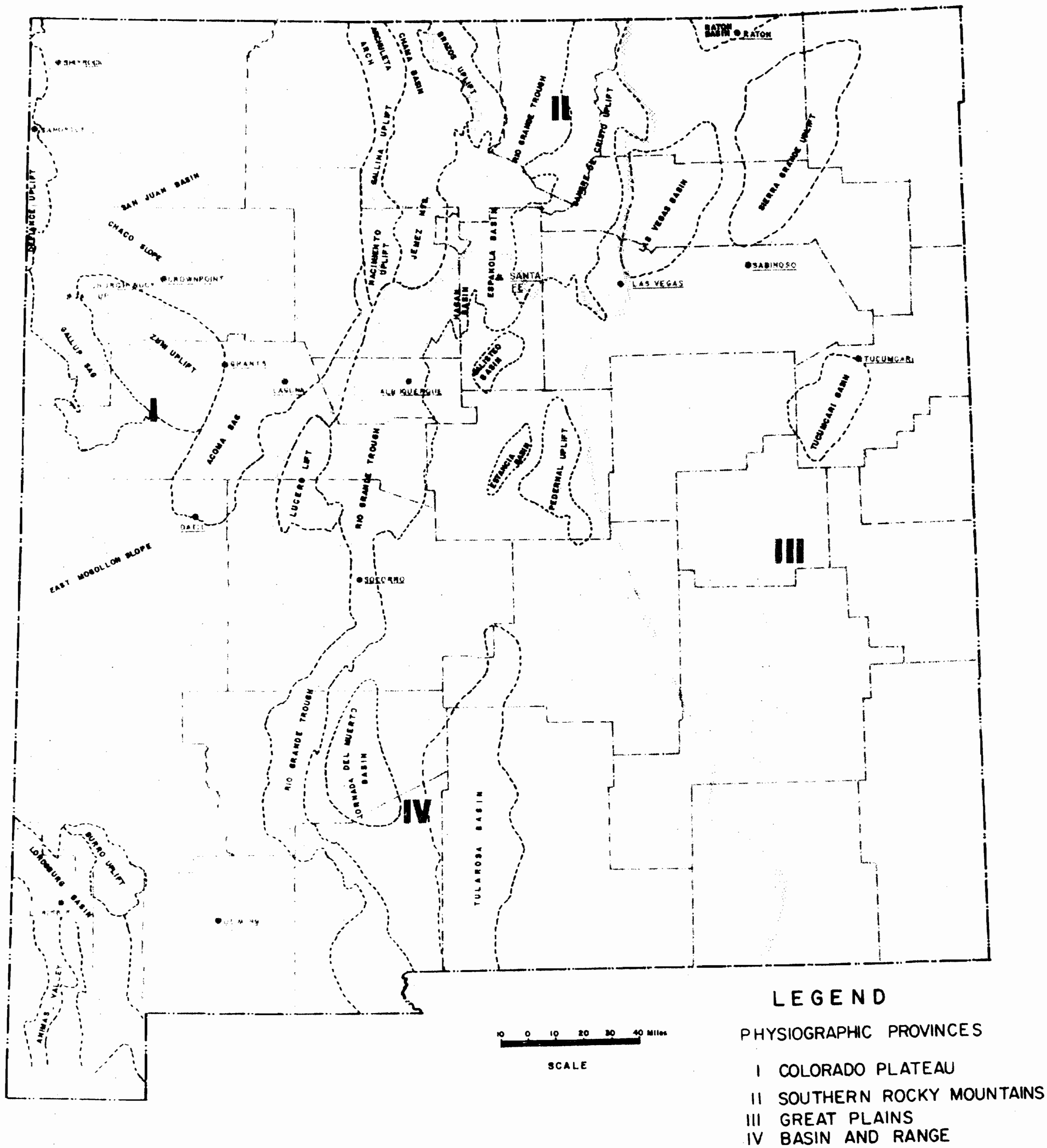


Table II-1. Uranium-bearing host rocks of New Mexico showing geologic age, tectonic or physiographic setting and physiographic province (New Mexico Bureau of Geology).

Formation or host rock	Geological age	Tectonic element	Physiographic province
Calcrete/basin-fill	Quaternary	Lordsburg, Animas Valley area	Basin & Range
Gatuna Formation	Quaternary	Llano Estacado	Great Plains
Tesuque Formation	Oligocene	Espanola Basin Rio Grande Rift	Basin & Range Southern Rocky Mountains
Popotosa Formation	Oligocene	Ladron Uplift	Basin & Range
Galisteo Formation	Eocene	Estancia, Galisteo and Hagan basins	Basin & Range
Baca Formation	Eocene(?)	East Mogollon Slope, Acoma Sag	Colorado Plateau
Ojo Alamo Sandstone	Tertiary-Cretaceous	East San Juan Basin	Colorado Plateau
Dakota Sandstone	Cretaceous	Southern San Juan Basin	Colorado Plateau
Burro Canyon Formation	Cretaceous	Chama Basin	Colorado Plateau
Morrison Formation Brushy Basin Shale, Westwater Canyon Ss., Recapture Shale Mbr. & Salt Wash Sandstone Mbr.	Jurassic	San Juan Basin Defiance Uplift	Colorado Plateau
Todilto Limestone	Jurassic	S. San Juan Basin, Defiance Uplift Chama Basin	Colorado Plateau
Chinle Formation	Triassic	Tucumcari Basin Sierra Grande Uplift	Great Plains
		Gallina Uplift	Colorado Plateau
		Nacimiento Uplift	Southern Rocky Mountains

(Table II-1 continued)

Formation or host rock	Geological age	Tectonic element	Physiographic province
Yates Formation	Permian	Sacramento Slope	Basin & Range
Sangre de Cristo Formation	Permo-Pennsylvanian	Las Vegas Basin	Great Plains
		Sangre de Cristo Uplift	Southern Rocky Mountains
Plutonic & Metamorphic rocks	Precambrian	Burro Uplift Pedernal Uplift	Basin & Range
		Brazos, Sangre de Cristo Uplift	Southern Rocky Mountains

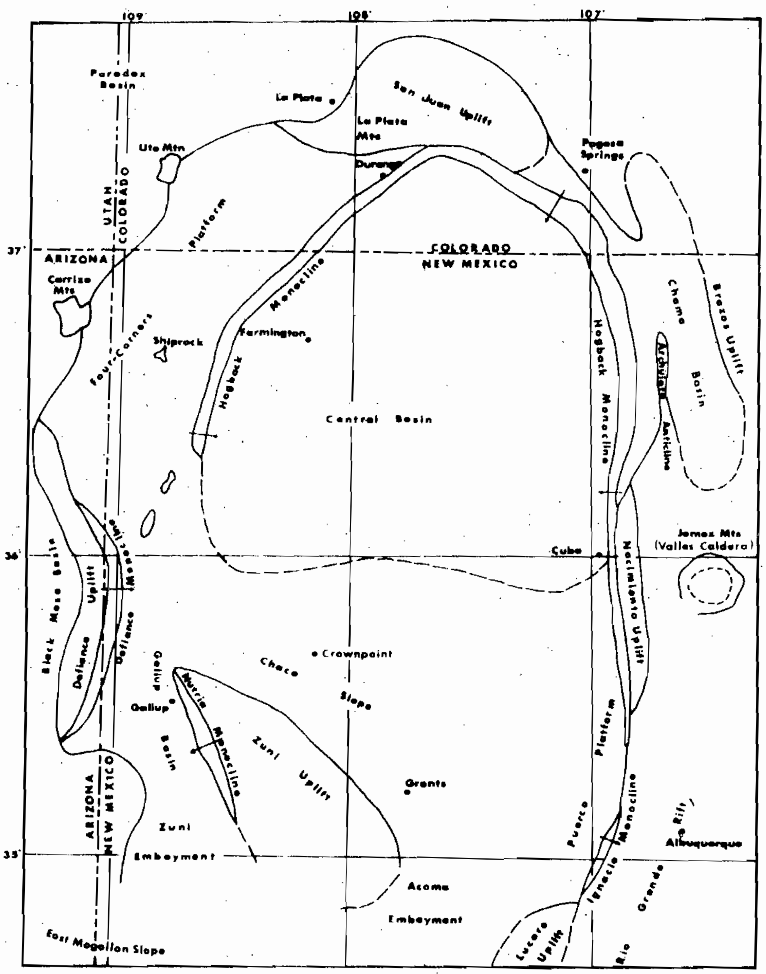
land to form the northeast edge of the basin. Further south, the Nacimiento Mountains define the eastern side, while the Lucero and Zuni uplifts form the southern boundary. Almost the entire western side of the basin is formed by the Defiance Uplift which begins at the Chuska Mountains north of Gallup and terminates in the Carrizo Mountains west of Shiprock. Intervening depressions between these uplifts include the Chama Embayment on the northeast, the Acoma Sag and McCartys syncline on the south, and the Gallup Sag on the southwest.

To the south of the basin, lies the Mogollon Slope, also known as the Datil section of the Colorado Plateau. In this location, Tertiary volcanic rocks generally cap older Tertiary and Mesozoic sedimentary strata, and faulting and folding become more intense than in the San Juan Basin to the north. Potential and known uranium deposits occur along a major unconformity between the Cretaceous Mesaverde Formation and the overlying Eocene(?) Baca Formation. Some potential might also occur in Miocene volcanics and associated sedimentary strata in the San Augustin Basin.

San Juan Basin

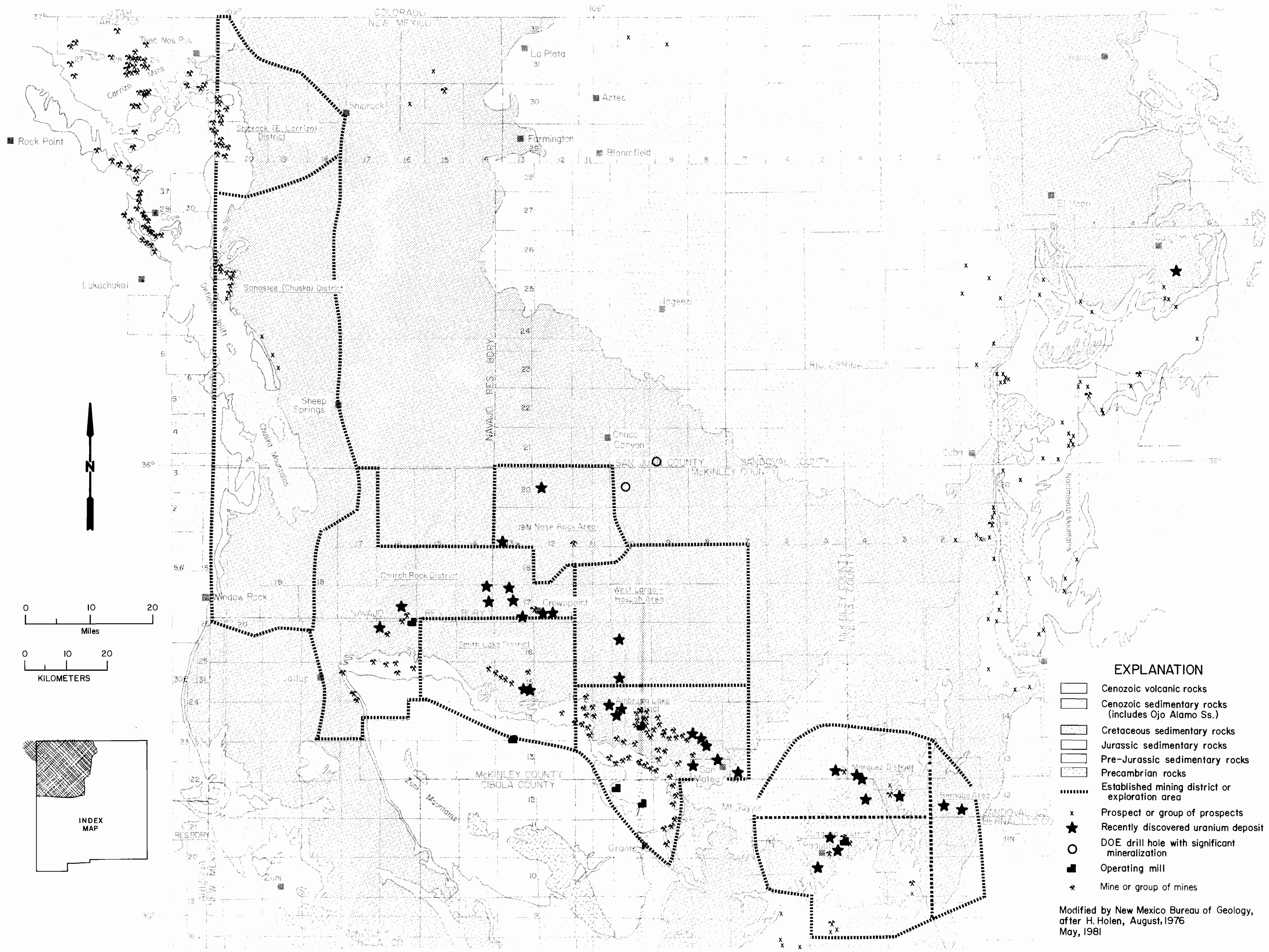
Two areas within the basin have been important centers of uranium production, the Grants Mineral Belt and the Shiprock-Sanostee area. Figure II-2 shows the area of the San Juan Basin. The Grants Mineral Belt contains the largest producing mines and the bulk of total uranium reserves in the United States. The area is approximately 100 miles long and 25 miles wide, stretching from the Gallup Sag near the Arizona border on the west to the Rio Puerco on the east. Structurally, the belt is nearly coincident with the Chaco Slope, which forms the gently dipping southern edge of the San Juan Basin north of the Zuni Uplift. With the exception of one, all of the state's active mines, both underground and open-pit, are located within the belt. Four mining districts have been delineated within the belt, and are, from west to east, the Gallup Church Rock, Smith Lake (Blackjack), Ambrosia Lake, and Laguna mining district (Figure II-3).

Figure II-2. Tectonic Map of the San Juan Basin and related tectonic features in the New Mexico portion of the Colorado Plateau physiographic province (modified after Fassett and Hinds, 1971, and Kelley, 1951).



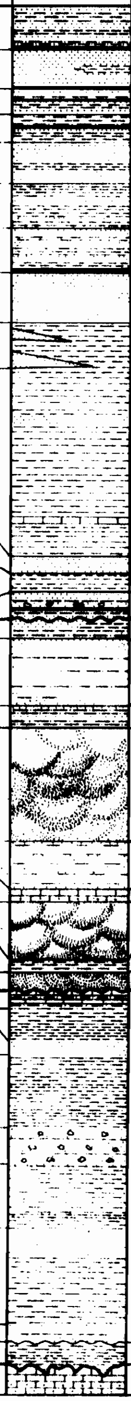
The largest known deposits occur in the Morrison Formation, although the Todilto Limestone has produced almost 2 percent of total historic New Mexico production. In the Grants Mineral Belt, two members of the Morrison Formation account for the bulk of production: the Westwater Canyon Sandstone Member and the overlying Brushy Basin Shale Member. Mineralization occurs throughout the Westwater from top to bottom, the unit ranging from about 90 ft to more than 290 ft in thickness. Brushy Basin deposits occur at the top of the member in a sandstone termed the Jackpile Sandstone of economic usage in the Laguna district, as well as within a stratigraphic zone of intertonguing between sandstones in the basal Brushy Basin and overlying Westwater canyon. Stratigraphic sections at Church Rock, Ambrosia Lake and Laguna are presented in Figures II-4, II-5 and II-6.

Figure II-3. Simplified Geologic Map of San Juan Basin in New Mexico and adjoining areas showing known uranium deposits, exploration areas, mines, mining districts, and operating mills (adapted from H. Holen, U.S. Department of Energy, 1976).



EXPLANATION
Cenozoic volcanic rocks
Cenozoic sedimentary rocks (includes Ojo Alamo Ss.)
Cretaceous sedimentary rocks
Jurassic sedimentary rocks
Pre-Jurassic sedimentary rocks
Precambrian rocks
Established mining district or exploration area
Prospect or group of prospects
Recently discovered uranium deposit
DOE drill hole with significant mineralization
Operating mill
Mine or group of mines
Modified by New Mexico Bureau of Geology, after H. Holen, August, 1976
May, 1981
INDEX MAP
Miles
KILOMETERS
COLORADO
NEW MEXICO
Rock Point
Lukachukai
Shiprock
Shiprock (E. Carrizo) District
Sanostee (Chuska) District
Sheep Springs
Farmington
Aztec
Bloomfield
La Plata
Chaco Canyon
SAN JUAN COUNTY
McKINLEY COUNTY
SANDOVAL COUNTY
Nose Rock Area
Church Rock District
Crownpoint
West Largo-Hospah Area
Window Rock
Smith Lake District
Gallup
Ambrosia Lake District
San Mateo
McKINLEY COUNTY
CIBOLA COUNTY
Zuni Mountains
Grants
Mt. Taylor
Marquez District
Zuni
Cuba
Nacimiento Mountains
NAVAJO RES. BDRY

Figure II-4. Stratigraphic section of the Church Rock area, McKinley County, New Mexico (Chenoweth, W.L., and Learned, E.A., 1980).

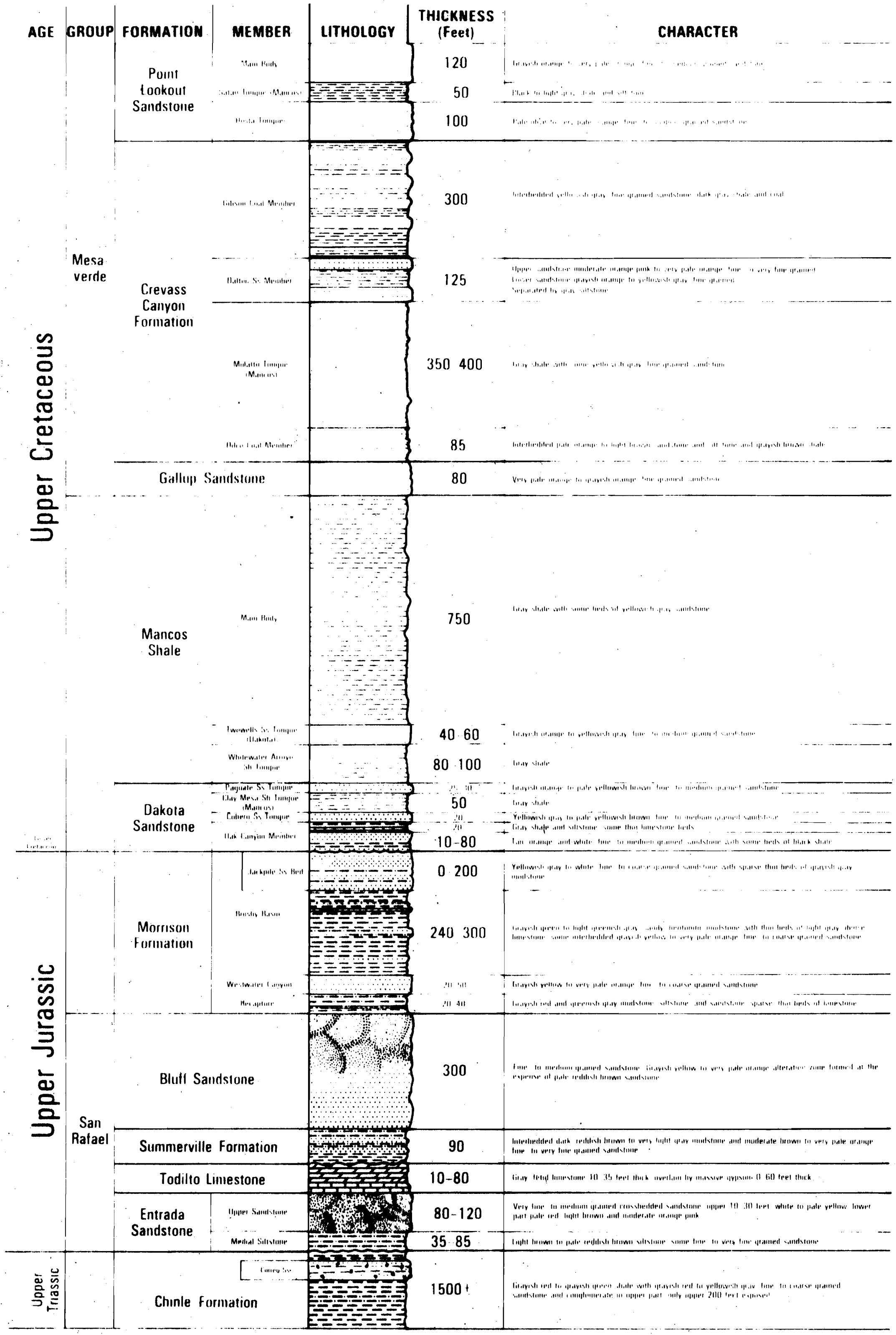


AGE	GROUP	FORMATION	MEMBER	LITHOLOGY	THICKNESS (Feet)	CHARACTER
Upper Cretaceous	Mesa-verde	Menefee Formation			800 +	Interbedded tan to brown, very fine- to medium-grained sandstone, siltstone, mudstone, gray shale, thin coal beds, top not exposed
		Point Lookout Sandstone			0-150	Yellowish gray to buff, fine- to very fine grained, massive sandstone
		Crevass Canyon Formation	Gibson Coal Member		100-300	Interbedded medium- to very coarse grained sandstone, siltstone, mudstone, thin coal beds
			Bartlett Barren Member		0-160	Interbedded yellowish gray to olive gray shale, siltstone, yellowish gray to white sandstone, carbonaceous shale, irregular coal beds
			Dalton Ss Member		130-150	Yellowish gray, fine- to very fine grained sandstone, split by tongue of Mulatto
			Mulatto Tongue (Mancos)		45-100	Light- to dark gray shale with thin beds of tan sandstone
			Dilco Coal Member		120-180	Interbedded light gray to yellowish-brown, fine- to medium-grained sandstone siltstone, shale, coal beds
		Gallup Sandstone	Main Body		65-200	Yellowish-brown to white, fine-to medium-grained, crossbedded sandstone
			Lower Beds			Yellowish-brown, very fine- to medium-grained sandstone toogues, 0-60 feet thick
		Mancos Shale	Main Body		500-700	Dark olive gray silty shale, indistinct beds of yellowish-brown sandy siltstone and silty sandstone. Thin limestone beds, intertongues with Mesaverde and Dakota
		Dakota Sandstone	Twowells Ss Tongue		20-60	Yellowish brown to buff, medium- to fine grained sandstone
			Whitewater Arroyo Sh Tongue (Mancos)		60-130	Dark gray to yellowish gray shale
Lower Cretaceous			Main Body		50-150	Yellowish-brown to buff, fine- to medium-grained sandstone, conglomeratic sandstone, carbonaceous shale, lignite
Upper Jurassic		Morrison Formation	Brushy Basin		0-100	Greenish- to purplish gray siltstone and claystone, lenticular beds of yellowish brown, pink, white, coarse-grained sandstone
			Westwater Canyon		100-250	Light red to reddish orange, white fine- to very coarse grained, crossbedded sandstone and conglomeratic sandstone, with lenses of siltstone
			Recapture		0-150	Reddish brown to brick red siltstone, white to greenish gray, fine- to medium grained sandstone
	San Rafael	Cow Springs Sandstone			300-500	Light greenish gray, pale orange, light reddish brown, fine to medium-grained, crossbedded, massive sandstone
		Summerville Formation			20-130	Reddish brown to greenish white, very fine- to fine grained silty sandstone
		Todilto Limestone			2-30	Light- to dark gray, sandy limestone
		Entrada Sandstone	Upper Sandstone		200-250	Reddish orange, fine- to very fine grained, massive, crossbedded sandstone
			Medial Siltstone		35-65	Dark- to light brick red sandy siltstone
			Iyanbito		80-140	Moderate reddish orange, fine-to medium grained, friable, crossbedded sandstone
Upper Triassic		Chinle Formation	Owl Rock		1400-2000	Interbedded purplish white to greenish gray, cherty, nodular limestone and siltstone
			Correo Ss Bed; Petrified Forest Upper			Dark- to light purplish gray and reddish gray siltstone and claystone, contains several thin fine- to coarse grained sandstone beds
			Sonsela Ss Bed			Light gray to yellowish brown, very fine-grained to conglomeratic sandstone interbedded with bluish grey mudstone and siltstone
			Petrified Forest Lower			Blue to gray and reddish purple mudstone and siltstone
			Monitor Butte			Gray, very fine- to fine grained, crossbedded sandstone and varigated siltstone
			Shinarump			Yellowish-gray, very fine- to coarse sandstone, siltstone
Lower & Middle (?) Triassic		Moenkopi (?)			0-50	Varigated siltstone, mudstone, silty sandstone, conglomerate
Permian		San Andres Limestone			0-145	Gray to yellowish gray limestone, upper surface karst, sandstone bed in lower part

Figure II-5. Stratigraphic section of the Ambrosia Lake area, McKinley and Valencia Counties, New Mexico (Chenoweth, W.L., and Learned, E.A., 1979).

AGE	GROUP	FORMATION	MEMBER	THICKNESS (Feet)	CHARACTER
Upper Cretaceous	Mesa verde	Point Lookout Sandstone	Main Body	60–160	Light gray and reddish brown, medium- to fine grained massive sandstone
			Satan Tongue (Mancos)	0–140	Dark gray sandy shale, some interbedded pale yellowish-brown, fined-grained silty sandstone and siltstone
			Hosta Tongue	100–140	Light gray, medium- to fine grained sandstone
		Crevass Canyon Formation	Gibson Coal Member	180–300	Light gray lenticular sandstone interbedded with gray siltstone, carbonaceous shale and coal
			Dalton Ss Member	60–150	Light gray, fine- to medium grained sandstone
			Mulatto Tongue (Mancos)	220–400	Pale yellowish brown, sandy shale, dark gray shale
			Borrego Pass Lentil	0–40	Gray, fine-, medium- and coarse-grained sandstone
			Dilco Coal Member	80–180	Yellowish gray, pale-orange sandstone, siltstone, carbonaceous shale, coal
		Gallup Sandstone	Main Body	0–120	Pale reddish brown and light gray, fine- and medium-grained sandstone
			Pescado Tongue (Mancos)	140–160	Dark gray, silty shale
			Lower Part	10–40	Gray, fossiliferous, fine- and coarse grained sandstone
		Mancos Shale	Main Body	600–650	Dark grey to black friable silty shale with minor light brown sandstone
			Twowells Ss Tongue (Dakota)	95–150	Yellowish brown to buff, medium- to fine grained sandstone
			Whitewater Arroyo Sh Tongue		Gray black shale
		Dakota Sandstone	Paguate Ss Tongue	50–90	Grey, very fine-grained sandstone
			Clay Mesa Sh Tongue		Dark grey shale (Mancos)
			Cubero Ss		Gray, very fine-grained sandstone
			Oak Canyon Member		
Upper Jurassic		Morrison Formation	Brushy Basin	85–160	Upper part—Light gray and grayish-tan, carbonaceous, very fine-grained sandstone and siltstone Lower part—Pale yellowish brown, orange, white, fine- and medium-grained sandstone
				40–220	Greenish gray mudstone with minor lenticular, light gray and yellowish-gray, fine- and medium-grained sandstone
			Westwater Canyon	90–290	Light yellowish- and reddish-gray, medium grained sandstone, with greenish-grey, lenticular mudstone
			Recapture	70–250	Interbedded variegated mudstone claystone, siltstone and sandstone
	San Rafael	Bluff Sandstone		235–370	White, light gray, grayish yellow, pale orange, and reddish-brown fine grained, massive crossbedded sandstone
		Summerville Formation		160–270	Interbedded variegated mudstone and siltstone, fine- to very fine-grained sandstone
		Todilto Limestone		25–35	Pale olive gray, dark olive gray, and pale yellow, thick bedded limestone
		Entrada Sandstone	Upper Sandstone	150–185	Moderate brown, fine grained, massive crossbedded sandstone
			Medial Siltstone	40–60	Grayish red brown calcareous siltstone
			Iyanbito	80–115	Moderate brown to moderate reddish orange, medium grained, crossbedded sandstone
Upper Triassic		Chinle Formation	Owl Rock	1100–1600	Greenish purple claystone and siltstone interbedded with pale blue to greenish-gray and pink limestone and silty limestone
			Correo Ss		
			Petrified Forest (Upper)		Moderate grayish red to pale reddish brown and purple mudstone, siltstone, and sandy siltstone
			Sonsela Ss Bed		White, light gray to yellowish gray, and brown very fine grained to conglomerate sandstone interbedded with varicolored claystone
			Petrified Forest (Lower)		Blue to gray and reddish purple mudstone and siltstone
			Monitor Butte		Grayish red claystone and sandy siltstone, fine- to medium grained sandstone, brownish gray conglomerate
Permian		San Andres Limestone		95–115	Dense gray and yellowish brown to red limestone with interbedded yellow, fine- to medium grained crossbedded sandstone, upper surface karst

Figure II-6. Stratigraphic section of the Laguna-Paguate Area, Valencia County, New Mexico (Chenoweth, W.L., and Learned, E.A., 1979).

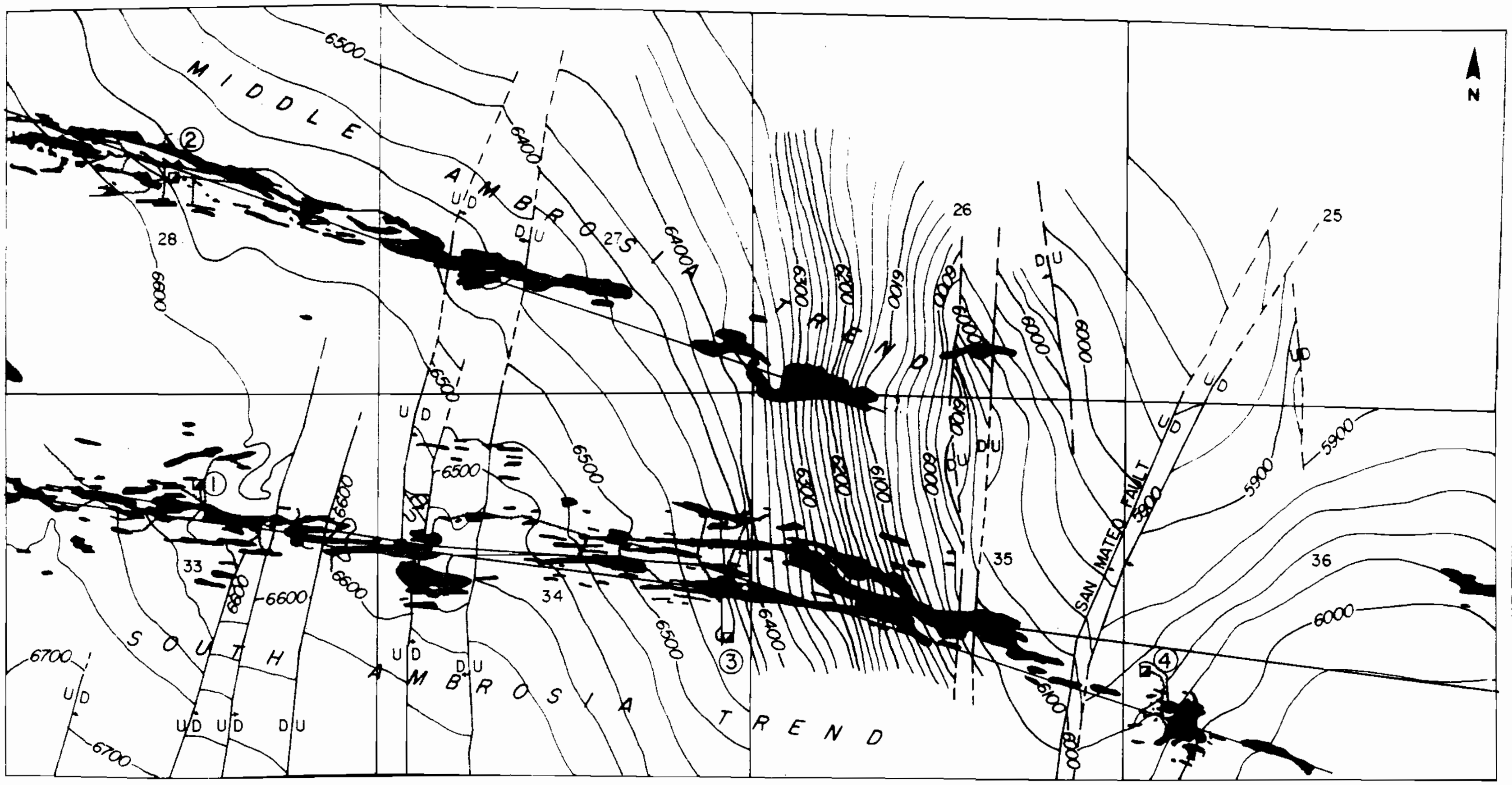


Most deposits in the Grants Mineral Belt are aligned in roughly parallel, en echelon trends within the Morrison that are tens of miles in length and usually less than a mile in width (Figure II-7). Individual deposits shown on the map resemble a string of sausages. Many ore deposits occur along oxidation-reduction fronts. The deposits generally follow major Morrison sedimentary depositional trends as composite, braided cut-and-fill "channels." The sandstone host rock is generally fine-to coarse-grained, feldspathic, and poorly sorted. Deposits are epigenetic and occur in three widely recognized forms: (1) tabular, (2) stacked or redistributed, and (3) roll-type (Figure II8). The uranium occurs as interstitial, grain-boundary coatings of coffinite (a potassium silicate of uranium oxide) and uraninite (primary uranium oxide) within sandstone host rocks. Carbonaceous plant matter and humate are not everywhere present but may occur intimately associated with the deposits.

Tabular and roll-type ore bodies may be several thousand feet in length, several hundred feet in width, and tens of feet in thickness (Figure II-8). Such deposits are thought to have no direct structural control but are controlled rather by favorable stratigraphic, sedimentologic, and geochemical criteria. On the other hand, stacked or redistributed ore bodies may be more erratic in morphology, somewhat en echelon in cross section or "stacked" nearly vertically along faults and fractures. Secular equilibrium is the state that exists when the number of disintegrations per second for each member of the uranium decay series is the same. It is observed less in redistributed deposits than in tabular or roll-type deposits, especially in the Church Rock and Smith Lake districts. Radiometric assays can be higher than chemical assays when a state of secular disequilibrium exists, and the resulting anomalous radioactive count can be misleading in evaluating a potential deposit at depth through drill-hole intercepts. Similarly, ore which is in disequilibrium presents a problem in mining as it does not carry the quantity of chemical uranium that would otherwise be detectable with scintillometer probes.

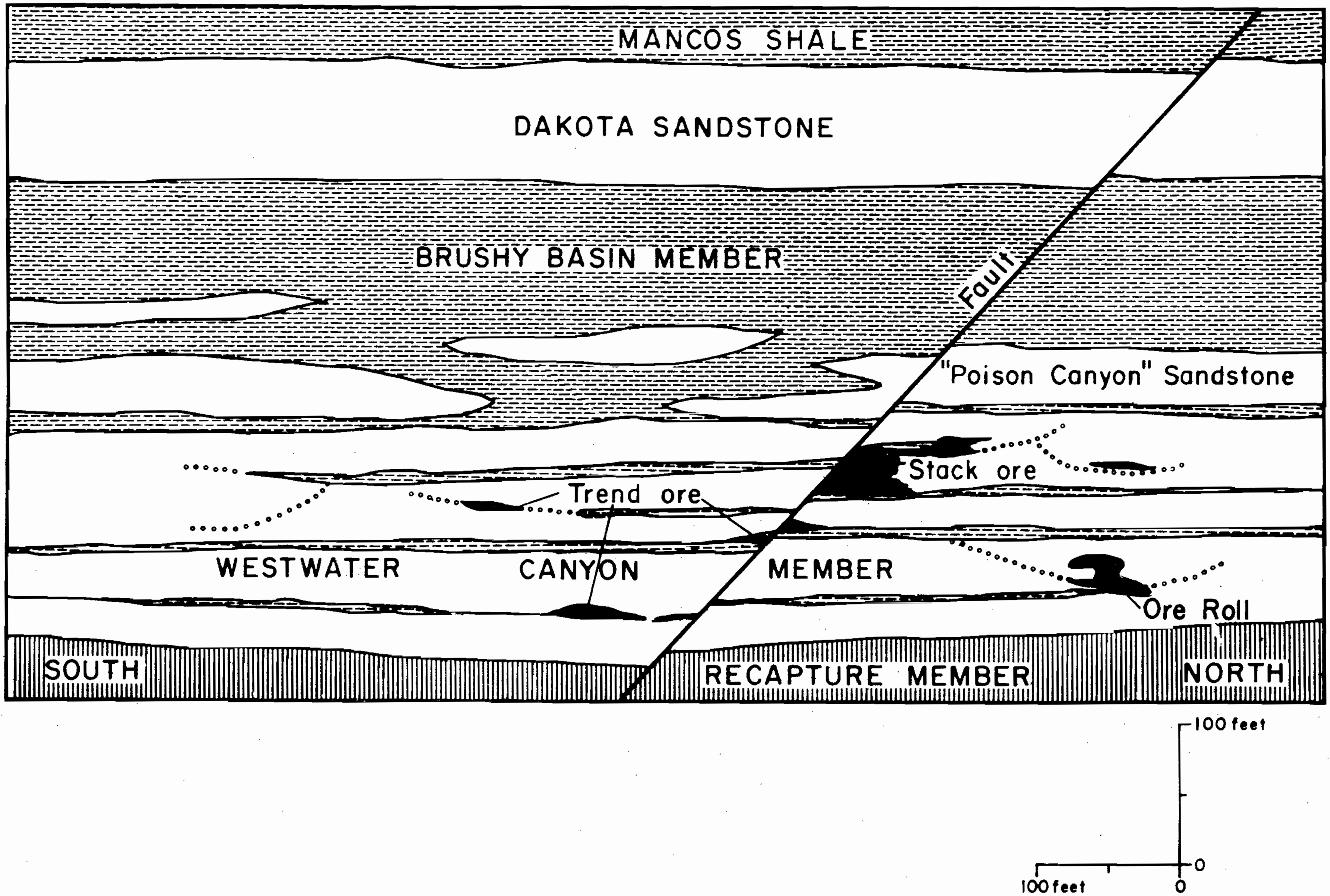
Trends have been delineated northward and basinward across the entire Chaco Slope through intensive exploration drilling programs since the early 1970's. Depths of mineralization may exceed 5,000 ft. Although the Nose Rock roll-front trend, discovered by Phillips in 1974, in T. 19N., R. 11W. and R. 12W., is presently recongnized as the northernmost basinward orebody, mineralization has been intercepted through deep drilling in T. 21N., R. 9W.,

Figure II-7. Ore distribution and structural contour map of the southeastern Ambrosia Lake area, T. 14N., R. 8W.; (Kelley et al., 1963, modified).



① Kerr McGee Section 33 Mine
② UNC Ann Lee Mine
③ UNC Sandstone Mine
④ Kerr McGee Section 36 Mine

Figure II-8. Generalized cross section through trend, stack and roll-type ore deposits, Grants Mineral Belt, New Mexico (modified from Chenoweth, 1979).



and R. 10W. in the Chaco Canyon National Monument area (Bendix Field Engineering Corp., 1980b and 1980d).

Todilto uranium mineralization is confined to lithologically favorable zones associated with fracturing, faulting, and/or biohermal structures within the Todilto Limestone. Because of the economics of the Limestone deposits, mining has been limited to shallow depths along the Todilto bench in the vicinity of Haystack Butte where the original Grants Mineral Belt discovery was made, and to some extent around Laguna to the southeast. Todilto ore has been produced from Box Canyon prospects in the Youngsville-Abiquiu area (Chenoweth, 1974). Trial shipments of uranium-bearing Todilto limestone have also been made from the Sanostee area on the western slope of the basin and the Chama Basin on the east. Todilto ore has also been produced at the Box Canyon prospect in the Youngsville-Abiquiu area (Chenoweth, 1974). The uranium geology of Todilto Limestone deposits is discussed by Rawson (1980).

The second important uranium producing area in the San Juan Basin is the Sanostee area located southwest of Shiprock in the Chuska mining district. Important deposits have been mined from the Recapture and Salt Wash members of the Morrison Formation where uranium-vanadium deposits occur in fluvial sandstones. The Shiprock district to the north of Sanostee has also been important in terms of past production in New Mexico. Deposits occur in the Salt Wash Member where fluvial sandstones and interbedded mudstones are favorable host rocks. The Salt Wash is the lowest member of the Morrison and is present only in the northwestern part of the San Juan Basin. Blagbrough and others (1955) have studied the uranium geology of the Salt Wash and Recapture deposits in the Sanostee area. The two Morrison members have different source areas resulting in the occurrence of favorable Salt Wash host rock north of the Sanostee area and distinctly differing ore controls in the two units. In the East Carrizo area, the Salt Wash is the principal host rock. Where distributary sandstone channels merge into floodplain deposits, localized carbonaceous debris and abrupt lateral changes in permeability have produced highly favorable loci for uranium mineralization (Blagbrough, personal communication, June 1980). Depositional environments as ore controls in the Salt Wash of the Carrizo Mountain area are discussed in a paper by Huffman and others (1980). On the other hand, in the Sanostee area where the Recapture member is the principal host rock, ore is controlled by large intraformational mudstone galls and calcareous concretions in channel sandstone units. Unlike Salt Wash deposits, carbonaceous matter does not appear to be abundant or as important as an ore control. Abundant interstitial mud may be derived from altered feldspars as a source for the uranium. Sandstones near uranium occurrences are leached white in contrast to the usual reddish or salmon colored Recapture (Blagbrough, personal communication, June 1980). Other host rocks for uranium in the San Juan Basin include the Dakota Sandstone, the Mesaverde Group of Cretaceous age and the Ojo Alamo and San Jose formations of Tertiary age. The Dakota is mineralized at several localities in the Gallup-Ambrosia Lake and Cuba areas, and has recorded production especially in the Gallup-Church Rock area.

Uranium-bearing lignitic coal and shale in the Menefee Formation of the Mesaverde Group near La Ventana south of Cuba has been studied by Bachman and others (1959) at North Butte. The Fruitland Formation of late Cretaceous age is mineralized in an area northwest of Farmington.

The Burro Canyon Formation of Early Cretaceous age contains uranium in the Canjilon area of the Chama Embayment. Saucier (1974) has described the formation, its relationship to Jackpile Sandstone in the Laguna district, and its uranium occurrences.

The most current collective work describing the geology of individual uranium deposits in the Grants uranium region is Memoir 38, published by the New Mexico Bureau of Mines and Mineral Resources, and entitled "Geology and mineral technology of the Grants uranium region 1979".

Southern Rocky Mountains

Two major prongs of the Southern Rocky Mountains extend into New Mexico from Colorado. The eastern prong consists of the several folded, anticlinal ranges of the Sangre de Cristo Mountains. The western, largely volcanic prong enters at the Colorado border between Chama and Tres Piedras as a southern extension of the San Juan Mountains, and culminates in the Jemez Mountains south of the Valles Caldera near Los Alamos. The Rio Grande Rift separates the two areas of the New Mexico Rockies and is a zone of deep crustal faulting more transitional with the Basin-Range province to the south.

Uranium occurrences in the New Mexico Rockies are confined largely to two types of geologic settings: (1) vein and pegmatite occurrences associated with Precambrian granitic and metamorphic rocks, and (2) epigenetic occurrences in sedimentary strata. Chenoweth (1979) has described many of the vein and pegmatite occurrences in the ranges of the New Mexico Rockies as well as the sedimentary types. Uranium-bearing pegmatites are known in the Rincon Range (Elk Mountain district) west of Las Vegas. Seven such pegmatites have been investigated in addition to the Old Priest pegmatite in Section. 26, T. 15N., R. 14E. The principal uranium mineral in the pegmatites is identified as samarskite in association with thorium and rare-earths. To date, the pegmatites are thought to be too sporadic to encourage additional exploration.

Both pegmatites and fractured Precambrian metamorphic rocks are known to contain uranium minerals in the Picuris Range west of Dixon in Rio Arriba County. Radioactive minerals have also been noted in pegmatites in the Truchas Range east of Espanola, and sedimentary rocks in adjacent areas (the Tesuque Formation of Pliocene age) are also known to contain uranium mineralization in association with carbonaceous zones and clay galls.

To the west, in the Tusas-Brazos Uplift between Chama and Tres Piedras, the Petaca pegmatites contain sparsely disseminated uranium (samarskite) in pegmatites and in quartz-fluorite veins (Chenoweth, 1974). The occurrences are associated with commercial mica deposits and are considered uneconomic in themselves, although the area has never been intensively investigated.

Basin and Range Province

The Basin and Range physiographic province constitutes most of southwestern and central New Mexico where block-faulted mountain ranges alternate with intervening basins, mostly trending in a north-south direction. Mountain ranges include, among others, the Ladron, Caballo, Guadalupe, Burro, Sacramento, Sandia, Sierra Blanca (White), and Hueco mountains. The Estancia Basin, Rio Grande Rift, Jornada del Muerto, and Animas Valley are among the important intervening basins of the New Mexico portion of the province.

The block-faulted ranges typically have Precambrian cores which are capped with Tertiary volcanic, and Mesozoic and Paleozoic sedimentary rocks. The adjacent basins are floored with the same strata which are in turn covered with hundreds of feet of Tertiary and Quaternary sedimentary and volcanic rocks derived from the nearby ranges. Uranium occurrences are thus found in a variety of geologic settings: (1) the highly faulted and fractured bedrock of the ranges either as a hydrothermal vein or fracture-type deposits, or disseminated magmatic or contact metasomatic deposits within the granitic cores or associated metamorphic rocks; or (2) in sedimentary strata within the ranges or in the adjoining basin-fill as epigenetic deposits; or (3) as occurrences in a wide range of volcanic rocks.

One unique occurrence of uranium is found at the La Bajada mine located in the Santa Fe River canyon southwest of Santa Fe. Here, the mineralization is in the Espinaso Volcanics (Oligocene) where the formation is intruded by a limburgite dike (Chenoweth, 1979). Although uranium minerals have been detected nearby on joint surfaces of the Cienequilla Limburgite and in sedimentary rocks of the Santa Fe Group (Pliocene-Pliestocene), the potential for locating additional economic occurrences is considered relatively poor due to the restrictive nature of this type of deposit.

In the Socorro region, two principal properties have recorded uranium production, the Jeter mine north of Socorro, and the Lucky Don prospect east of Socorro. The Jeter mine is developed in a sheared fault contact between the Popotosa Formation of Miocene age and a Precambrian granite. The recorded production from the Jeter is 8,826 tons of ore, which has averaged 0.33 percent U_3O_8. No production has been recorded since the 1950's (Holen, personal communication, July 1980).

The Lucky Don prospect is located in Section 25, T. 25N., R. 2E. east of the Rio Grande in Socorro County. The occurrence is along a northeast trending fault zone between the Permian San Andres Limestone and the underlying Yeso Formation, also of Permian age. Total production has been 1,022 tons of ore averaging 0.22 percent U_3O_8 (Holen, personal communication, July 1980). Although additional occurrences are known in the area of T. 3 & 4 S., R. 2E., they have recorded only minor production.

Several companies have indicated interest in favorable basin-fill and associated evaporite (calcrete) environments in Hidalgo County near Lordsburg, the Animas Valley basin in particular. Other Basin-Range occurrences include small vein deposits in the Socorro vicinity, Socorro and Sierra counties, and disseminated uranium mineralization in the Burro Mountain granite in Grant and Hidalgo counties of southwestern New Mexico.

Sedimentary occurrences in the Eocene Galisteo Formation of the Hagan Basin in Sandoval and Santa Fe counties have been delineated and are currently under development (Moore, 1979). Similarly, the Galisteo appears to be favorable for additional uranium resources beneath the Galisteo, Hagan, and Estancia basins in Santa Fe, Sandoval, and Torrance counties. The overlying Espinaso Volcanics and adjacent Precambrian Pedernal and Sangre de Cristo uplifts may be likely sources of mineralization within the Galisteo Formation.

Great Plains Province

In New Mexico, the Great Plains province lies east of the Sangre de Cristo (Southern Rocky) Mountains and the Pecos River. Sedimentary strata that comprise the plains province range in age from Paleozoic to Quaternary. In the northeastern part of the state, Cretaceous strata are locally overlain by Quaternary volcanic rocks as at Capulin Mountain. To the south, on the Llano Estacado, the plains are capped with caliche deposits of the Ogallala Formation (Pliocene-Pleistocene). Where the Pecos and Canadian rivers have deeply dissected the plain, rocks largely of Permian and Triassic ages are exposed as in the Canadian escarpment and the Pecos River Valley. Faulting is generally lacking, but gentle folds, domes, and flexures are evident throughout the New Mexico portion of the province.

Several stratigraphic units ranging in age from Permian through Quaternary have known occurrences of uranium. These include, from oldest to youngest, the Sangre de Cristo Formation of Permian and Pennsylvanian age in the Las Vegas Basin; the Yates Formation of Permian age at Rocky Arroyo near Carlsbad; the Dockum Group (Chinle) of Late Triassic age at several localities near the Pecos River, along the Canadian escarpment and in the vicinity of Tucumcari; the Morrison Formation of Jurassic age; and the Gatuna Formation of Quaternary age in north-central Lea County (Finch, 1972).

In almost all instances, mineralization is associated with organic matter in sandstones and dolomites. The Chinle occurrences in the Sabinoso district along the Canadian escarpment in San Miguel and Mora counties appear to be related to the Sierra Grande arch since all deposits are south of the arch which apparently influenced sedimentation during the Triassic. The deposits occur in a middle sandstone unit of the Chinle Formation and appear to replace organic debris in channel sandstones (Wanek, 1962).

CHAPTER III

EXPLORATION BY THE URANIUM INDUSTRY

Exploration Highlights, 1979 - 1980

The San Juan Basin continued to be the prime area of exploration activity as newer and deeper mineralized trends within the Westwater Canyon Sandstone Member of the Morrison Formation have been drilled basinward, thus extending the Grants Mineral Belt northward. Mineralized intercepts at depths in excess of 4,500 ft. have been reported near Chaco Canyon (Bendix Field Corp., 1980). New exploration concepts continue to be revealed including the announcement by Phillips Uranium Corporation of a large roll-type deposit at its Nose Rock project northeast of Crownpoint. The Phillips discovery of large-scale roll-type deposits in the Westwater Canyon Member is the first recognition of this particular type of deposit in the San Juan Basin of New Mexico, where roll-front morphology and geochemistry were employed as primary exploration and development guides. Roll-type deposits have been described within the Grants Mineral Belt as early as 1972 (Kendall), but their morphology and geochemistry had not been successfully employed as oreguides prior to the Nose Rock discovery. A geologic description of the Nose Rock deposit is presented by Clark (1980), and roll-front exploration criteria are discussed by Rhett (1980).

In addition to the Phillips Nose Rock ore trend, three distinct and somewhat parallel mineralized trends appear to have been delineated in the Crownpoint vicinity through intense exploration drilling since the early 1970's. To date, some 75 million lbs. of U_3O_8 reserves have been delineated within these three trends, which are as yet only vaguely defined and somewhat open-ended to the east and west. Other areas within the San Juan Basin that are being explored include the eastern and western extremities of the Grants Mineral Belt at Bernabe-Montano and at Church Rock, respectively, the western San Juan Basin near Sanostee, and the eastern San Juan Basin or Chama Embayment near Canjilon. Major new deposits and extensions of known deposits continue to be discovered and delineated within and north of the known Grants Mineral Belt. Church Rock, Pinedale, Dalton Pass, Crownpoint, Nose Rock, Borrego Pass, West Largo, Hospah, Mount Taylor, Marquez and L-Bar Ranch are all areas where exploration and development drilling is reported to be concentrated. Other areas within the basin beyond the fringes of the mineral belt have also received limited exploration drilling. Minor discoveries within these areas will have to await more favorable uranium market economics before they can be developed or further investigated for economic feasibility. The Westwater Canyon, Salt Wash, and Recapture Members of the Morrison Formation are the exploration targets near Sanostee, and the Burro Canyon Formation is the target in the Chama Embayment. To the south, there has been limited success in defining mineralization on the East Mogollon Slope in the Datil-Quemado area, where the exploration target is the unconformity between the Cretaceous Mesaverde Group and the overlying Eocene (?) Baca Formation.

During early 1980, Phillips Uranium submitted a proposal to the Carson National Forest to drill between 12 and 19 exploration holes in Rio Arriba County near Tres Piedras but that project has been cancelled after 6 months of environmental and regulatory delays.

Plans for exploration drilling in the Galisteo Basin south of Santa Fe have been announced by Exxon. The Galisteo Formation of Tertiary age has been selected as the target since this stratigraphic unit is also known to be the host of a deposit in the nearby Hagan Basin which is currently being developed by Union Carbide. Lone Star Mining and Development Company has filed plans for additional exploration at the inactive La Bajada mine site located 4 miles west of La Cienega in Santa Fe County.

As a result of the U.S. Department of Energy's NURE (National Uranium Resource Evaluation) program, a radioactive anomaly was discovered on the southwestern flank of Costilla Peak in the Culebra Range of northern New Mexico in Taos County. The anomaly occurs in an area underlain by Precambrian granite and pegmatite dikes, both of which may be a likely source. Although the anomaly is still under investigation, stream sediment, rock, and water samples are being collected along the principal drainage, Costilla Creek. Some sediment samples are reported to range up to 7,688 ppm (parts per million) U_3O_8, rock samples to 461 ppm U_3O_8, and water samples from 59 to 380 parts per billion (Reid et al., 1980).

Exploration Techniques

Historically, exploration techniques have included geologic mapping and sampling, radiometric, geophysical and geochemical surveys from the air and ground, the sinking of test pits, trenching, rim stripping by bulldozers, and drilling. Evidence of early uranium exploration activities can be seen throughout the Grants-Ambrosia Lake area in the form of abandoned drill roads, prospect pits, and drill sites. New techniques include but are not limited to geochemical and heavy mineral criteria associated with roll-type deposits, oxidation-reduction (redox) zone recognition, helium surveys, radon monitoring using a patented track-etch device, computer modeling, and direct measurment of uranium by pulsed-neutron borehole logging.

Drilling

Since all surface outcrops of uranium ore have probably been discovered, the exploration effort today is concentrated on detecting subsurface deposits, with the Westwater usually being the target. Some "wildcat" frontier type of exploration, however, is being undertaken, including areas outside the San Juan Basin. Drilling is the only technique which can be used to determine the actual occurrence of ore bodies below the earth's surface. Drilling rigs vary in size and type. Since some drilling is being conducted at depths of as much as 5,500 ft., rigs capable of deep penetration are necessary. Nearly all of the drilling is by truck-mounted rotary rigs capable of drilling 5 3/4 or 7 7/8-inch diameter holes. The upper part of the hole may be drilled by air to the water table and the remainder of the hole drilled by water and mud. A tricone rock bit is used for drilling. Diamond bits are used for coring.

The rig operator may lay out drill cuttings on the ground near the rig (one line of small samples representing 100 ft.) taken at designated intervals (usually 5 ft.). The staff geologist then analyzes these samples and may reserve portions for laboratory analysis. Normally, all cuttings are bagged and retained for future study.

If the hole is core drilled, the geologist must specify exact footage intervals to be cored within zones of interest. This selection of core point and core interval is vital since the sample obtained will be the only relatively undisturbed specimen of the mineralized rock. Cores are split vertically into two or more portions; one portion retained for safe-keeping and other portions for assay and geologic and engineering testing.

A more detailed account of exploration methods in the Grants Mineral Belt of New Mexico can be found in New Mexico Bureau of Mines and Mineral Resources Memoir 38, in an article by David C. Fitch, (1980).

Geophysical Uranium Borehole Logging

When the borehole reaches the geologist's assigned TD (total depth), it is logged. The mineral industry usually contracts a private geophysical company to provide this logging service. Basically, uranium borehole logging involves sending an instrument package or "probe" down the hole, making measurements during its ascent, and recording the data. The desired result of this 1-2 hour operation is a geophysical log, usually comprised of gamma-ray, S.P. (self-potential), and resistivity curves. All three parameters are graphically recorded on paper as a function of depth and have related, yet distinct, applications.

The gamma-ray curve is a measurment (in counts per second) of the natural radioactivity of a formation. Because the daughter elements of uranium spontaneously emit gamma rays, a scintillation device within the probe is employed to detect these radioactive emissions. Once the natural gamma data is recorded, the resulting log can be used to interpret specific amounts of equivalent U_3O_8 (uranium oxide) in a particular zone (Fitch, 1971). Ore-grade calculations based on interpretation of a gamma rerun prove relatively accurate in the Grants Mineral Belt; however, methods of interpretation coupled with certain hole-specific factors can influence ore value determinations. Conditions under which the gamma log was recorded (i.e., borehole diameter, K-Factor, dead-time, water factor), therefore, must be taken into account. Other uses of the gamma curve are: Ore reserve calculation, wide-spaced profile analysis, correlation and mine planning.

Two electric logs applicable to uranium exploration are self-potential and resistivity. The SP voltage potential differences are measured (in millivolts) between two electrodes: a lead nose on the ascending probe and a lead "mudfish" in the surface mudpit. The voltage potentials develop in the borehole by electrochemical, oxidation-reduction, and electromechanical action between the minerals and the solutions with which they are in contact. Information provided by the SP log is useful for location of stratigraphic boundaries; identification (lithology) of rock type, e.g., sandstone, shale, etc.; and correlation with other logs (Century Geophysical Corporation, 1975). The resistivity curve also serves as an important correlation tool during this phase of exploration. Because resistivity is a basic electrical property of rock materials closely related to their lithology, passage of a constant current through an electrode into surrounding formations will result in a voltage drop which can be detected and recorded. The formation water conducts this current almost totally, making the sequential log largely a measure (in ohms) of formation water resistivity. Formation porosity can then be calculated through interpretation of this curve. (see Figure III-1)

During exploration drilling, the borehole may "drift" in attitude from the true vertical (for many practical reasons). To accurately determine the location of the hole, a vertical deviation survey is performed. A deviation-sensing tool, sometimes mounted in the probe, takes down-hole readings of various components of the earth's magnetic and gravitational fields. Orientation of the tool itself, with respect to these components, is determined and integrated into overall deviation calculations. Results of this survey provide data of the hole's distance and direction from true vertical, which is important in determining the exact location and position of a subsurface ore body. Figure III-2 contains an illustration of a vertical deviation survey along with pertinent hole information.

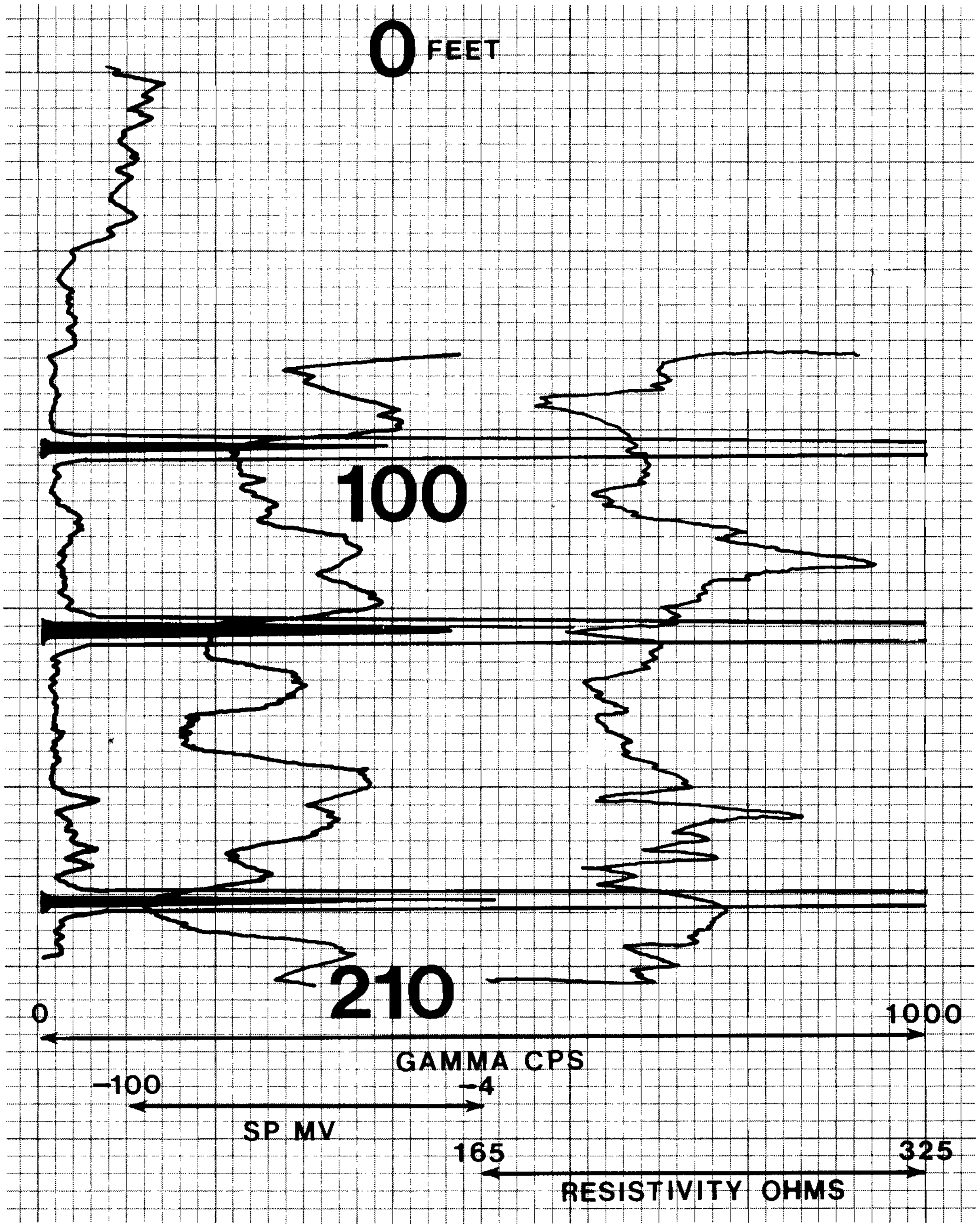
Presently two systems of log recording equipment are available, each mounted in specially designed, high-clearance vehicles. The conventional "analog" system immediately records the borehole data on graph paper as the ascending probe relays the information uphole. The "digital computer" system allows real-time data signals from the probe to be monitored on a video display terminal and recorded simultaneously on magnetic tape. The tape is then processed by computer and plotted in graph form. While both systems provide accurate, reliable borehole data, industry preferences exist with relation to price, function, and specific needs.

Once the borehole has been logged, it must be plugged according to specifications established by the State Engineer and mandated by state statute (NMSA 69-3-6). This procedure is a necessary precaution to prevent inter-aquifer connections and possible future surface flow and to insure underground mine safety when development reaches that stage.

<u>Land Holdings</u>

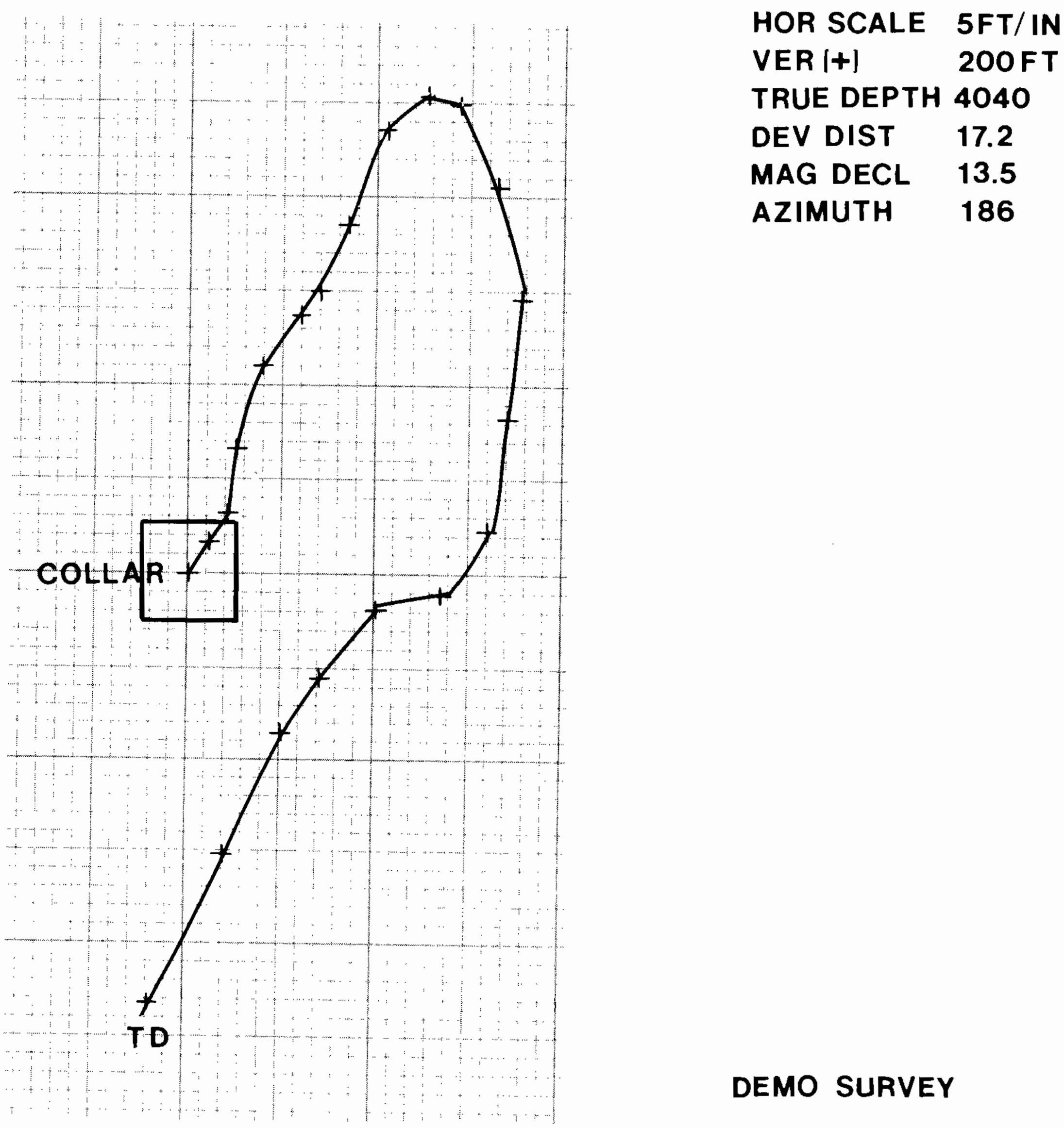
Among the 14 Western states where lands are held for uranium exploration and mining, New Mexico ranks third in total acreage held. Wyoming ranks first, with Utah second, and Colorado fourth after New Mexico. The distribution of lands by the six leading states is as follows: (after Figures 1 & 2)

Figure III-1. Geophysical log depicting the three basic curves utilized in uranium exploration. Three zones of mineralization (90 ft., 130 ft., and 190 ft.) are contained in the gamma curve; (Century Geophysical Corporation, 1980)



DEMO LOG

Figure III-2. Illustration of a vertical deviation survey; (Century Geophysical Corporation).



(Distribution of lands by the six leading states)

State	Acreage
Wyoming	12,416,000
Utah	7,038,000
NEW MEXICO	4,652,000
Colorado	3,901,000
Arizona	1,662,000
Texas	1,539,000
Other 8 states	3,953,000

Cumulative annual acreage held by county in New Mexico for uranium exploration and development during 1979 is shown in Table III-1. Land transactions in acres by county, including lease terminations and claim abandonments, are also shown.

Table III-1

APPROXIMATE ACREAGE HELD BY COUNTY AND LAND CATEGORY
(Bendix Field Engineering Corporation, 1980a)

Period	State	Claim	Federally acquired	Indian	Fee	Total
CUMULATIVE TOTAL to January 1,1979	431,461	2,098,515	608	386,215	1,362,390	4,279,189
Total January 1 to June 30, 1979 (see previous report)	(30,284)	305,140			26,940	301,796
Land transactions July 1 to December 31, 1979						
Bernalillo	(4,596)					(4,596)
Catron	26,055					26,055
Dona Ana	2,206					2,206
Grant	5,357					5,357
Guadalupe	2,879					2,879
Hidalgo	11,737					11,737
Lincoln	(1,440)					(1,440)
Luna	7,762					7,762
McKinley	(2,113	2,440				327
Otero	1,370					1,370
Rio Arriba	(2,077)					(2,077)
Sandoval	1,044	1,100				2,144
San Juan	(1,283)					(1,283)
Santa Fe	(341)					(341)
Sierra	5,170					5,170
Socorro	14,551					14,551
Valencia	796					796
Total July 1 to December 31, 1979	67,077	3,540				70,617
Total for calendar year	36,793	308,680			26,940	372,413
CUMULATIVE TOTAL to January 1, 1980	468,252	2,407,195	608	386,215	1,389,330	4,651,602

Table III-2 indicates the land held for uranium exploration and mining from 1974-1980.

Table III-2

LAND HELD FOR URANIUM EXPLORATION AND MINING IN NEW MEXICO

(U.S. Department of Energy, 1980a)

Date	Thousand Acres	Percent of Total U.S.
1/1/74	3,158	17
1/1/75	3,378	16
1/1/76	3,663	16
1/1/77	3,885	14
1/1/78	3,855	13
1/1/79	4,279	13
1/1/80	4,652	13

This table shows that the amount of land held for uranium exploration and mining in New Mexico has increased very little in the last 5 years and percentages of New Mexico's share of the United States total has dropped. This decline is probably due to the continuing concentration of interest in the San Juan Basin area, with the Westwater receiving most of the target drilling. Since the occurrence of uranium in the San Juan Basin has been known for several years (see Chapter I), most of the available areas of interest have already been obtained through claims and lease agreements.

This acreage has been distributed among state, federal, Indian, and private (fee) land as follows:

Ownership	Acreage
Federal (claim)	2,407,000
State	468,000
Indian	386,000
Federal (acquired)	1,000
Total	4,652,000

Surface Drilling

In 1979, a total of 40 million ft. was drilled in the United States for uranium exploration and development. Areas of drilling interest included shallow low-grade deposits in Wyoming, and areas in Texas, Utah, Colorado, and western Arizona. Table III-3 shows drilling activity in New Mexico in the past few years and indicates the percent of total United States drilling this has represented. As the table shows, 1976 was an important year for drilling in New Mexico. The activity in that year led to a large incr^ase in the state's reserves.

Table III-3

DRILLING IN NEW MEXICO FOR URANIUM EXPLORATION AND DEVELOPMENT
(U.S. Energy Research and Development Admin., 1976-1977; U.S. Department of Energy, 1978, 1979a, 1980a)

Year	Thousands Feet	Percent of Total Drilling in U.S.
1975	5,698	21.9
1976	11,020	32.4
1977	9,100	22.2
1978	9,922	21.1
1979	6,277	15.5

A total of 6,277,240 ft was drilled in 153 exploration and development projects during 1978. This activity in New Mexico represents 15.5 percent of total United States drilling, as compared with 21.1 percent in 1978, 22.2 percent in 1977, 32.4 percent in 1976, and 21.9 percent in 1975. The average hole depth in New Mexico was 860 ft.

The 1979 New Mexico total includes 3,199 exploration holes for a total of 1,989,823 ft drilled and 4,100 development holes for a total of 3,287,417 ft drilled. As in 1978, McKinley County claimed the bulk of all exploration and development drilling, although Valencia and San Juan counties continued to show extensive drilling activity. The drilling in San Juan County reflects to some drgree the effort that has been expended on deep drilling near Chaco Canyon as well as drilling on the Navajo Reservation. The drilling that took place in Catron County was principally undertaken to explore the Tertiary Baca Formation. Table III-4 shows surface drilling in New Mexico during 1979 by county.

Table III-4

URANIUM SURFACE DRILLING BY COUNTY IN NEW MEXICO DURING 1979
(W.L. Chenoweth, August 1980)

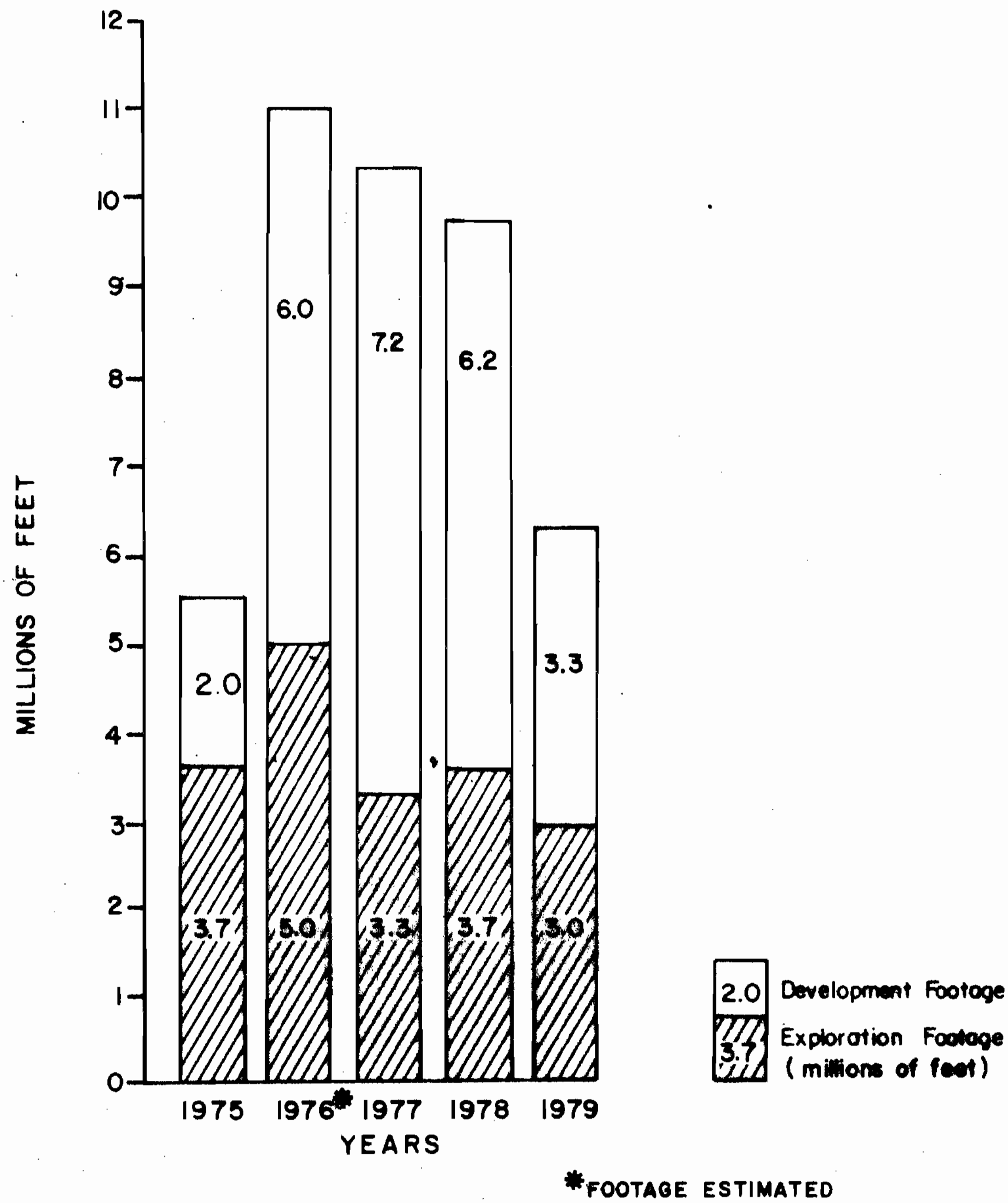
	Exploration		Development	
County	No. of Holes	Footage	No. of Holes	Footage
Catron	708	326,556	66	37,400
Sandoval	96	39,713	66	37,400
McKinley	1,748	1,975,484	3,834	3,058,467
San Juan	155	230,674	0	0
Valencia	219	220,150	220	191,550
Others*	273	197,246	0	0
Totals	3,199	2,989,823	4,100	3,287,417

* Includes Chaves, Grant, Rio Arriba, Sierra, Socorro and undisclosed.

Surface drilling is expected to decrease slightly in 1980 compared to 1979 and to decline further during 1981. According to the industry survey, total surface drilling in the United States between 1979 and 1981 should drop by about 14 percent. In New Mexico, surface drilling has declined by 18 percent since 1976 (Fig.III-3) when exploration and development drilling of newly discovered San Juan Basin ore deposits reached maximum intensity. The current decline is expected to continue over the next few years as exploration incentive is further eroded in New Mexico and other uranium-producing states by adverse market pricing, regulatory uncertainties, and ultimately, the lack of a coherent national energy policy toward nuclear energy. Figure III-4 shows the number of exploration and drill rigs reported in the state since 1976. In addition to the annual seasonal fluctuation, a pronounced decrease in rigs can be seen during the four-year period. A 59 percent decline in the total number of active rigs can be seen between September 1977 and September 1980.

Exploration drilling costs include site and road preparation, geological and other technical support, drilling, sampling, and drill-hole logging and cementing. During 1979, the average cost was $3.97 per ft of hole drilled, which is a 12 percent increase over 1978. In New Mexico, with deposits at greater depth, surface drilling costs in 1979 averaged $4.02 per ft. Although total budgeted exploration expenditures by industry are expected to fall through 1981, costs will continue to rise as in the past.

Figure III-3. Comparison of exploration and development drill footage in New Mexico between 1975 and 1979 (data from U.S. Department of Energy, 1976, 1977, 1978, 1979a and 1980a).



Planned exploration activities in frontier (non-established) areas and in non-sandstone deposits are expected to consume approximately 51 percent of industry's exploration budget by 1981. In 1979, such expenditures amounted to 48 percent. Although the emphasis in New Mexico is still on the San Juan Basin, potential resources are estimated to occur in frontier, sandstone, and non-sandstone geologic environments outside of the San Juan Basin.

Employment

During 1979, approximately 758 exploration personnel were employed in New Mexico compared to more than 1,000 during the previous year. Exploration employment statistics for the state by job category are shown below (W. L. Chenoweth, personal communication, August 1980).

Job category	Number of employees
Geology and engineering	172
Drilling services	345
Logging services	78
Aerial services	3
Others (landmen, surveyors, drafting personnel)	160
Total	758

More than 40 energy-resource companies were active in New Mexico during 1979. Most of these companies were engaged in one or more phases of land acquisition, exploration, development drilling, mining, and milling. The companies are listed below:

Anaconda (Arco)
Anschutz
Bokum Resources
Cobb Nuclear
Conoco
Energy Fuels Nuclear
Energy Reserves Group
Exxon
Frontier Mining
Getty
Gulf Minerals
Homestake Mining
Houston International Minerals
Keradamex
Kerr-McGee
Koppen Mining
Lone Star Mining & Devel.
Mining Unlimited
Mobil
New Cinch
Noranda Exploration
Nuclear Assurance
Occidental
Pathfinder
Phillips Uranium
Pioneer Nuclear
Ranchers Exploration & Devel.
REE-CO Energy, Inc.
Reserve Oil and Minerals
Resource Assoc. of Alaska
Rocky Mountain Energy
Robert Sayre
Santa Fe Mining (S.F. Railway)
Sohio
St.Joe Minerals
Teton Exploration Drilling
Thermal Energy
Todilto Exploration & Devel.
United Nuclear
United Nuclear-Homestake Partners
Union Carbide
Urania
Uranium King
Wesco
Western Nuclear (Phelps-Dodge)
Wyoming Mineral (Westinghouse)

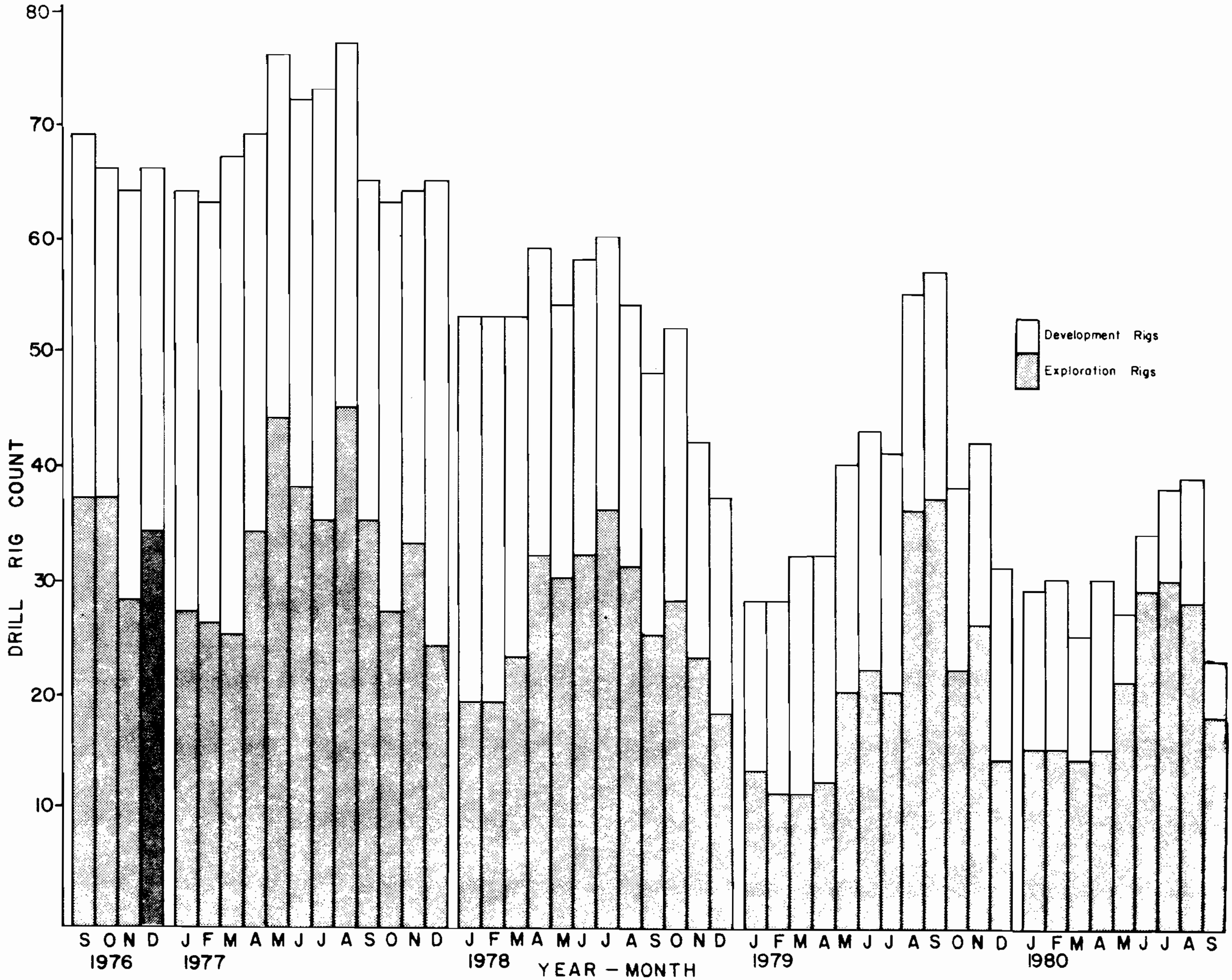


Figure III-4. Comparative exploration and development drill rig counts in New Mexico as reported by industry between September, 1976 and September, 1980 (data from New Mexico Uranium Newsletter, Evelyn Saucier, editor).

Expenditures

New Mexico expenditures for land acquisition, exploration and development can be calculated using data collected by the GJO (Grand Junction Office) of the U.S. Department of Energy for the United States as a whole.

In the data on United States expenditures reported by GJO, 41.1 million ft were reported drilled in the United States in 1979 at a cost of $163.0 million. Including land aquisition, companies reported spending $315.9 million on total exploration acivities. By using New Mexico's proportion (15.5 percent of total United States footage drilled) in combination with total United States surface drilling expenditures ($163.0 million), New Mexico uranium companies therefore put about $25.3 million into exploration in 1979. This would make expenditures in New Mexico average $4.02 per drilled foot. A total of $5.87 million was spent on land aquisition in New Mexico during 1979 which represents 13 percent of total national expenditures. This dollar percentage for New Mexico, however, is not representative of the State's true land aquisition expenditures because of a $10.3-million lease bid on a 640-acre tract of state land at Ambrosia Lake by Western Nuclear in late 1979. This single land transaction in itself caused the national per-acre land cost to soar from an average of $4.81 in 1978 to about $10.58 in 1979. Excluding this single land transaction, New Mexico land aquisition costs would average approximately $1.06 per acre. Land aquisition costs, however, can be expected to continue to increase rapidly because considerable exploration acreage has increased in potential mineral value due to the recent surge in total exploration investment, as exemplified by Western Nuclear.

Resource Requirements for Exploration Activities

The amount of fuel necessary to drill holes depends upon the types of rock drilled and the depth. Very little data is presently available to the state concerning energy use by drill rigs. One operator who reported drilling many feet at various depths (down to below 4,000 ft.) reported average diesel fuel consumption of 0.9 gallons per ft. Using this number, an estimate can be made of 9,450,000 gallons of diesel fuel consumed for drilling in New Mexico in 1977.

In addition to fuel used in drilling, fuel use should also include fuel used in equipment for pad construction, drilling pad preparation, and transportation of the drilling rig and materials to the drilling location (including worker transport).

Other resource uses include mud and water needed for drilling and for well plugging. One operator drilling at depths of 3,000 - 4,000 ft reports water needs to be 8,500 gallons per hole for drilling fluid and 420 gallons per hole for cement.

The typical drill pad occupies an area of approximately one-tenth of an acre or about 4,356 square ft.

Editor's Notes- By act of the Legislature, a new county, Cibola County, was created effective in July 1981. Cibola County comprises what was formerly western Valencia County with Grants designated as the county seat. As far as can be ascertained, all uranium statistics cited in this report for Valencia County will be applicable to the newly created Cibola County.

CHAPTER IV

MINING

Since uranium was first discovered in New Mexico in 1918, mining technology has become more complex and efficient in response to economics, types of geological occurrences, depths and environmental considerations. This chapter will review current New Mexico uranium mining technology including a description of the mining districts and mines themselves, the various types of extraction techniques including underground, open-pit and in-situ methods, as well as new mine developments and a review of mining and production costs.

The importance of ore grade expressed as percentage of U_3O_8 per ton of ore rock must be fully comprehended if one is to appreciate the definition of ore and its relationship to production and market economics. Ore is defined as mineralized rock at the minimum acceptable grade (% U_3O_8) that may be mined at a profit. Uranium is a totally fungible metal, that is, a pound of U_3O_8 concentrate (yellowcake) milled from a ton of ore is the same quality everywhere regardless of where the ore originated. Grade may then be expressed as the quantity of U_3O_8 concentrate in pounds contained in a ton of ore. High grade ore, therefore, yields more pounds of U_3O_8 per ton of ore mined. More rock must be mined, transported, milled, and disposed of in order to produce U_3O_8 from lower grade ores. Where appropriate, ore grades will be expressed in pounds of U_3O_8 per ton as well as percentage of U_3O_8 per ton.

The economic cut-off grade (COG) is defined as the minable grade limit of a uranium deposit that can be economically mined. COG can be expressed as an algebraic formula:

$$\frac{\text{Direct+Indirect Mining Costs+Haulage+Milling+Royalty+Severance Tax}}{\text{Sale Price per lb. } U_3O_8 \text{ X Mill Recovery Rate X 20}}$$

The reader will note that certain component costs within the formula, notably severance tax and royalty costs, remain fixed as others vary with geologic conditions, labor costs and market economics. Average mining costs are shown at the end of the chapter.

Techniques

The first areas, in general, to be mined for uranium in New Mexico were the easily discovered ores near the surface and in outcrops. The barren surface material was removed for deposits down to 60 ft. The ore removal was either carried out in a typical pit-type operation, or, in some cases, channels were excavated which followed the ore body. If the ore body extended deeper from the pit area, adits were constructed in some cases to recover the ore. Outcrops and fairly shallow ore bodies too deep for pit mining were usually recovered using adits, inclines, or declines. When underground deposits were discovered at Ambrosia Lake, vertical shafts were sunk. Some of these old shafts were wood-lined. In comparison to today's maximum depths, the shafts were fairly shallow. Only small headframes (often constructed of wood) were necessary.

Although some new mines are being constructed in those areas which were productive in earlier years, the trend is for new mines to be at greater depths. In general, these mines are below the water table and may require dewatering and cooling.

After development drilling has delineated the ore body, the sites for the production and ventilation shafts are determined. The chief considerations in locating a shaft are general topography, distance of underground ore haulage, and geology of the ore body.

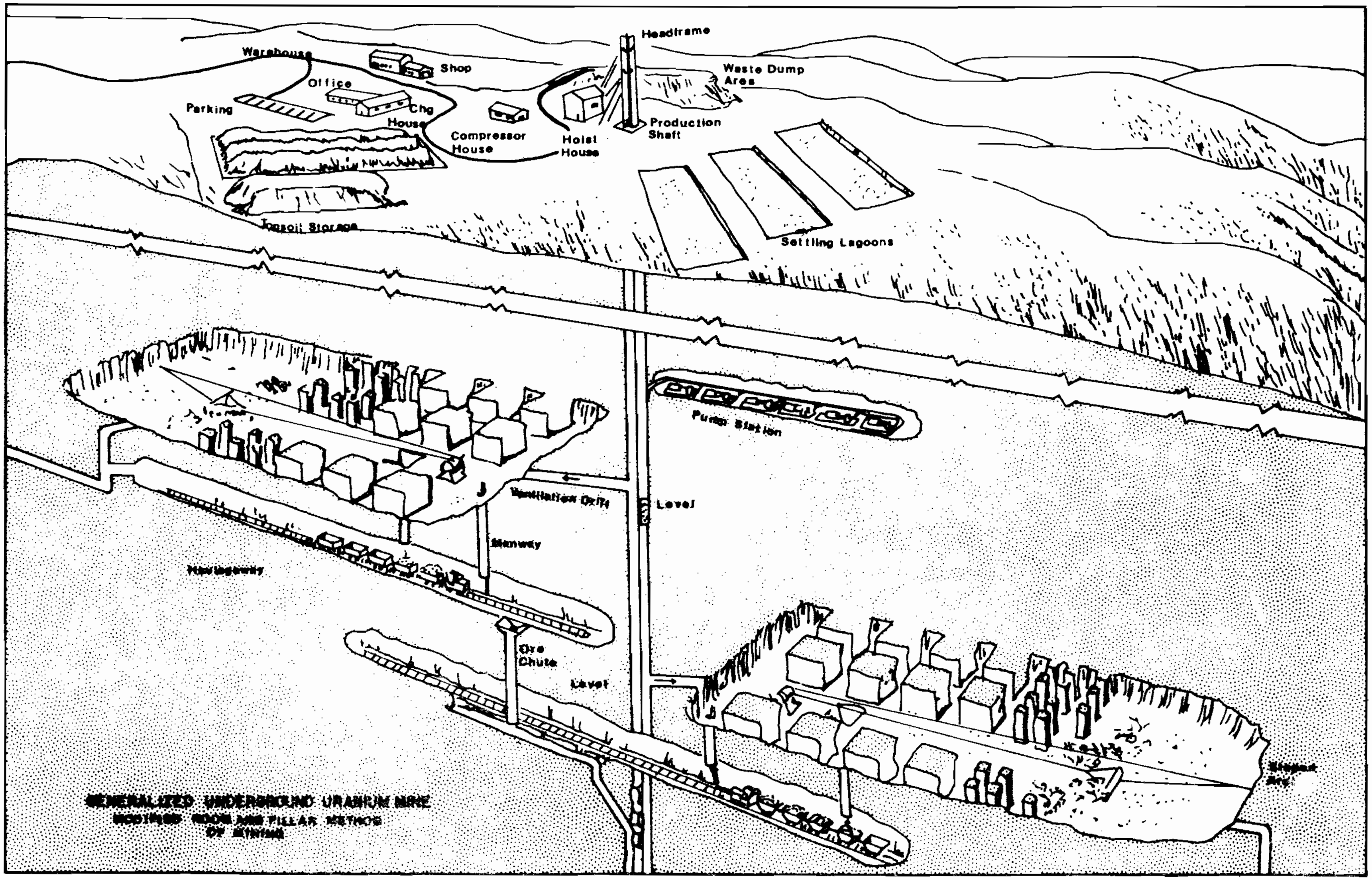
To begin a shaft, the footings for the concrete collar are poured and the collar is constructed. The headframe is then installed to allow for the hoisting of material from the shaft interior. To advance the shaft depth, blast holes are generally drilled, the area is blasted, the waste rock or muck is hoisted, the forms for the concrete lining are put into position, and the lining increment is poured. The process is repeated until the target depth is reached. Power lines and pump stations are carried downward as shaft excavation proceeds. In some cases, it may be necessary to drill dewatering wells in order to create a depression cone around the shaft as sinking proceeds. Grouting is used to seal off water just before and during penetration of the aquifer. Some companies have considered freezing the shaft area before sinking the shaft in order to avoid dewatering problems. Other companies have first drilled the shaft and then enlarged it. Conoco is using a modified shaft drilling method to sink their shafts at Crownpoint.

In wet mines, the shaft is usually sunk to some depth below the ore body in order to allow for pumping stations and haulage levels to be constructed below the mining area. Long-hole drilling at points along the haulage ways is used to facilitate the dewatering of the ore body. In mines which are dry, the haulage ways are usually on the ore level itself. Figure IV-1 shows a cross section of a generalized underground mine. A glossary of mining and other terms is included as Appendix B.

The Kerr-McGee Rio Puerco mine was brought into production in 1979, although it is currently inactive. The description of this mine's development, taken from the company's mining plan, is included to indicate the general development techniques used in opening up a wet mine.

"The mine-development phase consists of establishing sufficient access to the ore bodies to permit the production tonnage rate desired to be sustained. In the case of underground mining, this involves sinking a shaft which has been located to optimize the haulage distances from the various ore-producing areas. Once the shaft is sunk to the ore depth, a station with ancillary drifts, pockets, trenches, and sumps is developed.

Figure IV-1. Generalized underground uranium mine, modified room and pillar method (modified from UNC/TVA Draft Environmental Statement, September 1977).



The shaft at Rio Puerco will be 14 ft ID (inside diameter), circular, concrete-lined, with two hoisting compartments. In each hoisting compartment, there will be a man cage with a 3-ton-capacity skip suspended below the cage.

The time required to complete this size shaft to a depth of 850 ft will be 550 to 650 days. This period includes completion of a pump station at 700 ft and the pocket and slusher trenches.

Before and during the shaft's construction, surface support facilities are also being constructed. The main pad area includes a main and auxiliary building, a shaft-pad area, a power facilities area, perhaps a concrete batch plant (depending on economics of concrete delivery in the area), an ore storage pad, and a materials storage yard. The main building, as normally planned by Kerr-McGee, contains the hoist room, warehouse, maintenance shops, personnel shower and change rooms, and some engineering and administrative offices.

The area is fenced to prevent livestock entry. Inside or adjacent to the main yard area will be the topsoil stockpile, ore stockpile, water-treatment facilities, and the waste-rock dump. The main area to be fenced at the Rio Puerco project encompasses 72 acres.

Topsoil is removed and stacked to be used for reclamation when operations cease. The pile is seeded to prevent its erosion while stored. The ore stockpile provides surge so the mine and/or transportation system can act independently of one another.

The waste-rock pile consists of barren rock produced by the shaft sinking and development headings. Attempts are made to locate this pile in an area to minimize its erosion and possible leaching by rainwater of any potential pollutants.

Total accumulation of waste rock generated by the mine project is estimated to be 370,000 tons. At the cessation of operations, some of the reserved topsoil will be placed over this pile and seeded to minimize erosion and leaching of the waste rock and to aesthetically blend it into the surrounding terrain.

The water-treatment facilities are placed in a favorable gravity flow (from shaft) position with discharge access to the local drainage.

Once the shaft and surface work is completed, mine development continues with the driving of horizontal drifts outward from the shaft and beneath the elevation of the ore zone(s). These drifts are approximately 9 ft-by-9-ft high and supported for safety purposes by rock bolts, wood sets, and/or steel sets. Haulage drifts generally parallel the long axis trend of the ore bodies. Short drifts, called crosscuts, are driven normal to the haulage drift as required to reach the extremeties of the ore bodies.

These drifts are advanced by the standard drill, blast, and muck cycle. Typical development equipment includes mucking machines, jackleg drills, diesel locomotives (4-to-8-ton capacity) and 110 cubic ft rail cars which travel on 36-inch guage track. Haulage drifts may also be excavated by mechanical mining machines such as the Alpine Miner. Haulage drifts are driven on a positive one-quarter-to-1-percent grade to favor loaded trains and provide drainage toward the shaft.

As the drifts extend farther away from the shaft, the ventilation system is also developed by drilling ventilation holes. Their positions are based on the location of the ore bodies, and, of course, are consistent with the overall plan of mining.

The holes are bored by a surface rig. Two methods are employed; one in which the rig bores down on a pilot hole, or a second method in which the bit is attached at the bottom of a pilot hole and the hole is reamed upward. This work is done by a division of Kerr-McGee Nuclear or a contractor. The holes are usually 48 to 60 inches in diameter and cased with a steel liner which is cement grouted. Larger holes may be employed for deeper mines.

These holes are normally used for exhaust with the fresh air intake being the production shaft. By strategic placement of these holes, the ventilation system underground is able to maintain air quality (particularly for radiation standards) as required by federal and state mine safety regulations.

Surface acreage required for each hole is minimal. Four acres are needed as pad area while the hole is being drilled. After completion, approximately 3½ acres are reclaimed leaving a half-acre plot fenced around the vent hole and its fan installation.

Ore bodies are entered through raises driven from the haulage or crosscut drifts. Separate raises are generally driven for manways, ore passes, and service raises either through the conventional drill/blast cycle or with the use of raise-boring machines. From the haulage drifts, rotary long holes are drilled up to delineate the ore bodies for purposes of planning the raises.

Development in the ore horizon is accomplished by driving 5 ft-by-6-ft subdrifts within the ore. Initial development is followed by extensive long hole drilling laterally and vertically from the subdrift headings. The length of these holes normally does not exceed 40 ft. If sufficient ore is located by long hole drilling programs, development drifting will resume. Advance of such headings is through conventional drilling and blasting, and the muck is handled from the face to the muck raise by the use of 25 or 30 hp (horsepower) 3-drum electric slushers. At this point, an ore body's development phase is essentially complete.

As development of ore bodies nearest the shaft are completed and the ore bodies go into production, the development of more distant ore bodies continues. The transition from development to a production status is therefore gradual with some development continuing almost the entire span of the project. The development drifting in the ore bodies produces some ore and that activity also can be said to be the initial production. Kerr-McGee's current intention is to produce a maximum of 510 tons per day. Beginning with shaft collar construction, it will take approximately four years for the mine to reach full production.

Extraction (called "stoping") of an ore body begins once development is complete. There are generally three stoping methods employed by Kerr-McGee: (1) open stopes; (2) room and pillar stopes; and (3) square-set stoping. The object of each method is to extract as much of the ore (material defined as being above a certain minimum assay) as possible. These methods normally allow recovery in escess of 90 percent of the ore available. Maximization of a natural resource is thus accomplished, while simultaneously maximizing the project's profitability.

The final configurations of the stopes are based on several factors such as the ore body's shape, ground control in the stope, ventilation limitations, and roof control in the stope. Roof bolts, stulls, cribbing, timbering, and sandfill are variously applied as required. Sub-ore grade mineralized areas may be utilized as pillars for support where they occur.

Open stoping is employed in smaller ore bodies with roof bolts, and cribbing being mainly employed for roof control. Larger ore bodies of a more continuous nature will be extracted using the room and pillar method. After the development drifts (rooms) are driven, pillar begins at the furthest limit and the robbing activity retreats back to the raise. Slushers used in this phase are 30-to-75 hp, 3-drum type.

Square-set stoping is employed where the ore is continuous and of greater thickness. This is done to assure both adequate roof support and high extraction rates. The sill sets are minimally 8 ft in height with the "mining floors" (upper tiers) nominally constructed 6 ft in height. Final stabilization of a square-set stope may be accomplished by sandfilling once ore removal is complete.

The maximum tonnage rate will tail off as stoping is completed. At some point, ore depletion causes the project to become unprofitable at which time the decision is made to cease operations. This decision results in closure procedures being put into effect. Valuable equipment and other salvagable materials are stripped from the mine; then, a concrete plus will be poured at the collar of the shaft to seal the mine from unauthorized or accidental entry by man or animals.

The area of the ore stockpile will be thoroughly cleaned and the material sent to the mill. Trash and nonsalvagable material will be buried. The hoist headframe, buildings, and other structures will be removed. At the request of the surface owner(s), some buildings may be left intact for the owner to put to some other beneficial use.

Any foundations left from the structures removed will be destroyed. The areas disturbed will be graded and the topsoil will be redistributed. Seeding of the relaid topsoil will be done on the same basis with the same seed types as described in the section on exploration reclamation. Roads will be scarified and reclaimed if the owner does not want them for his own use."

Very few New Mexico mines use mechanical miners such as Alpines or Doscos. Most mines to date have been too small to justify the expense, and the ore bodies are so irregular that the machines can only be used for driving haulageways. Abrasion by the sandstone ores also causes high maintenance costs. United Nuclear's Church Rock mine, however, uses Doscos. A Dosco is in use at the United Nuclear-Homestake Partner's Section 13 mine and may be used at Gulf's Mount Taylor mine for development work there. An Alpine F6A has been used by Kerr-McGee at their Ambrosia Lake mines and an Alpine has been used by Anaconda.

The new, deeper mines are using shafts for ventilation rather than ventilating via boreholes because of the reduced energy requirements with the larger shaft areas. The deep mines will also use air-cooling equipment in order to keep the temperatures and humidity down to tolerable work levels (the temperature of the rock face at Gulf's Mount Taylor mine is about 130°F).

Some operators at deep mines which are being sunk have indicated that they feel that shaft dewatering wells have aided more than grouting in controlling infiltration. Selection of the proper grout is, of course, very critical. Depending on the success of the shaft freezing method, future deep mines may incorporate dewatering wells as a routine operation of shaft sinking.

Several mines in New Mexico have received or are receiving sand backfill. The status of sand backfill in New Mexico is given in Table IV-1. As was mentioned in the Rio Puerco mine plan discussion, sand backfill is normally used for structural support. The sand may be blow-sand or sand recovered from mill tailings. United Nuclear began backfilling operations using mill tailings at its Church Rock # 4 mine in February, 1980. Backfill using a gravity-fed wet-sand slurry is utilized in wet mines, whereas dry backfill injected pneumatically is a process being used in relatively dry mines. In the case of pneumatic backfill, a dry, sand-limestone aggregate mixture is used. Gulf Minerals is presently using the pneumatic method at their Mariano Lake mine.

The backfill method begins with the construction of a bulkhead at the entrance to the mined-out area. In the case of wet-sand slurrying, the dry sand is mixed with water. Water volume to sand volume ratio at the Johnny M is approximately 50:50, whereas the ratio is 70:30 at the Kerr-McGee mines. The mixture is slurried from the surface to the top of the bulkhead where it is subsequently deposited behind the bulkhead itself. Water drains from the sand into sumps where it is pumped back to the surface. Once the sand is drained, further stoping in front of the bulkhead can proceed without the danger of caving. Over 100 tons of sand per hour can be emplaced using this method. Sand backfill, when used successfully, allows for complete ore recovery in thick beds or zones where mine collapse and interaquifer connections would otherwise present an ever present problem.

Sand backfilling, however, is not always successful. In December 1977, backfilling was not successful at Kerr-McGee's Section 35 mine where a connection was made beteen the ore-bearing Westwater and overlying Dakota Sandstone through the intervening Brushy Basin Shale. The mine-dewatering rate almost doubled until the collapsed area was sealed off.

Another mining technique in use is called mine-water recirculation. Mine-water recirculation allows for the recovery of uranium in solution with recirculated mine-water through extremely low-grade areas that would otherwise

Table IV-1. Sand backfilling in New Mexico uranium mines (data from New Mexico Energy and Minerals Department).

Company	Mine or Proposed Mine	Has had Backfill	Will have Backfill
UN-HP	Ambrosia Lake Mines	Yes	-
Ray Williams	Enos Johnson	Yes	No
Bokum	Marquez*	-	If necessary
Kerr-McGee	Lee	-	If necessary
Kerr-McGee	Sec.17**	No	If necessary
Kerr-McGee	Sec.19	No	If necessary
Kerr-McGee	Sec.12	Yes	Yes
Kerr-McGee	Sec.24**	No	If necessary
Kerr-McGee	Sec.30	Yes	Yes
Kerr-McGee	Sec.30 W.	No	If necessary
Kerr-McGee	Sec.33	No	If necessary
Kerr-McGee	Sec.35	Yes	Yes
Kerr-McGee	Sec.36	Yes	Yes
Kerr-McGee	Church Rock No.1	No	If necessary
Kerr-McGee	Rio Puerco**	No	If necessary
Kerr-McGee	Church Rock No.2	-	If necessary
Ranchers	Johnny M	Yes	Yes
Gulf	Mariano Lake	Yes	Yes, dry
Gulf	Mount Taylor	-	Yes
Cobb	Sec.12	Yes	Yes
Conoco	Bernabe*	-	If necessary
Conoco	Borrego Pass*	-	If necessary
Conoco	Crownpoint	-	If necessary
UNC/TVA	Dalton Pass*	-	Waste rock if necessary
UNC	Old Church Rock	-	Yes
Phillips	Nose Rock No.1&2*	-	Yes
UNC	St. Anthony**	-	If necessary
UNC	N.E. Churchrock	-	Yes
Sohio	J.J. No.1	-	Yes

* Under construction or planned

** Temporarily inoperative

be non-economic to mechnically mine, areas that are usually too dangerous for miners to enter, and/or collapsed areas of uranium mining . As retreat mining developes within the mines, the backs (roofs) are allowed to collapse leaving significant tonnages of unmined mineralized material (not necessarily ore by economic definition). Such material is usually below the ore grade cutoff.

If collapse occurs, further ore recovery using traditional technique was difficult and dangerous. To further increase the recovery of low-grade ore, the mine-water recirculation technique is employed. As it has developed, the technique begins when holes are drilled from above the top of the collapsed zone and water is injected into the low-grade, shattered, and mineralized rock. Mine water is slightly alkaline so that a small amount of leaching will occur as it percolates downward through the shattered zone into collection sumps. The uranium-enriched water is then pumped to central IX (ion-exchange) facilities where the uranium is removed; then, allowing for discharge of any excess water, the stripped effluent water is returned to the mine for further leaching. Water recirculation is periodically stopped to allow for further oxidation within the collapse zone, thus increasing the leachate once water recirculation is resumed.

The first reported application of mine-water recirculation in New Mexico mines was that of United Nuclear-Homestake Partners in early 1964 (Wyrich, 1977). Mines undergoing mine-water recirculation are shown in Table IV-2 in the active mines section of this chapter.

Water from mine dewatering is also run through the ion exchange plant is many cases in order to recover the uranium. While the amount of uranium produced from mine waters is rather small (less than 1 percent of total production), this extraction process is economic and hence represents a small profitable operation for the mine owners. Such auxiliary recovery techniques have become more important as increased costs of mining and severance taxation further reduce profitability.

Another type of uranium-recovery technique is the in-situ leaching method. In a project currently being tested by Mobil near Crownpoint, injection wells are drilled approximately 100 ft apart. Weak alkaline solutions containing an oxidant are injected into the nine outer wells and the leached solution is recovered through four center production wells. The pregnant leachate is then passed through an ion-exchange column containing resin. The uranium will be removed from the resin in another column, precipitated, and concentrated. In order to contain the leachate and to have a successful operation: (1) the ore zone must be saturated, (2) there must be a net production of water, (3) the ore body must be uniformly permeable, and (4) it is helpful to have impermeable material overlying and underlying the ore-bearing unit. Figure IV-2 illustrates the major aspects of this type of extraction technique. The present New Mexico project is designed to recover uranium from depths of around 2,000 ft and, if successful, will be a first for in-situ recovery from this depth. A list of on-going or planned in situ recovery projects in New Mexico may be found in Chapter V. (Milling) as well as a more detailed discussion of in-situ recovery methods.

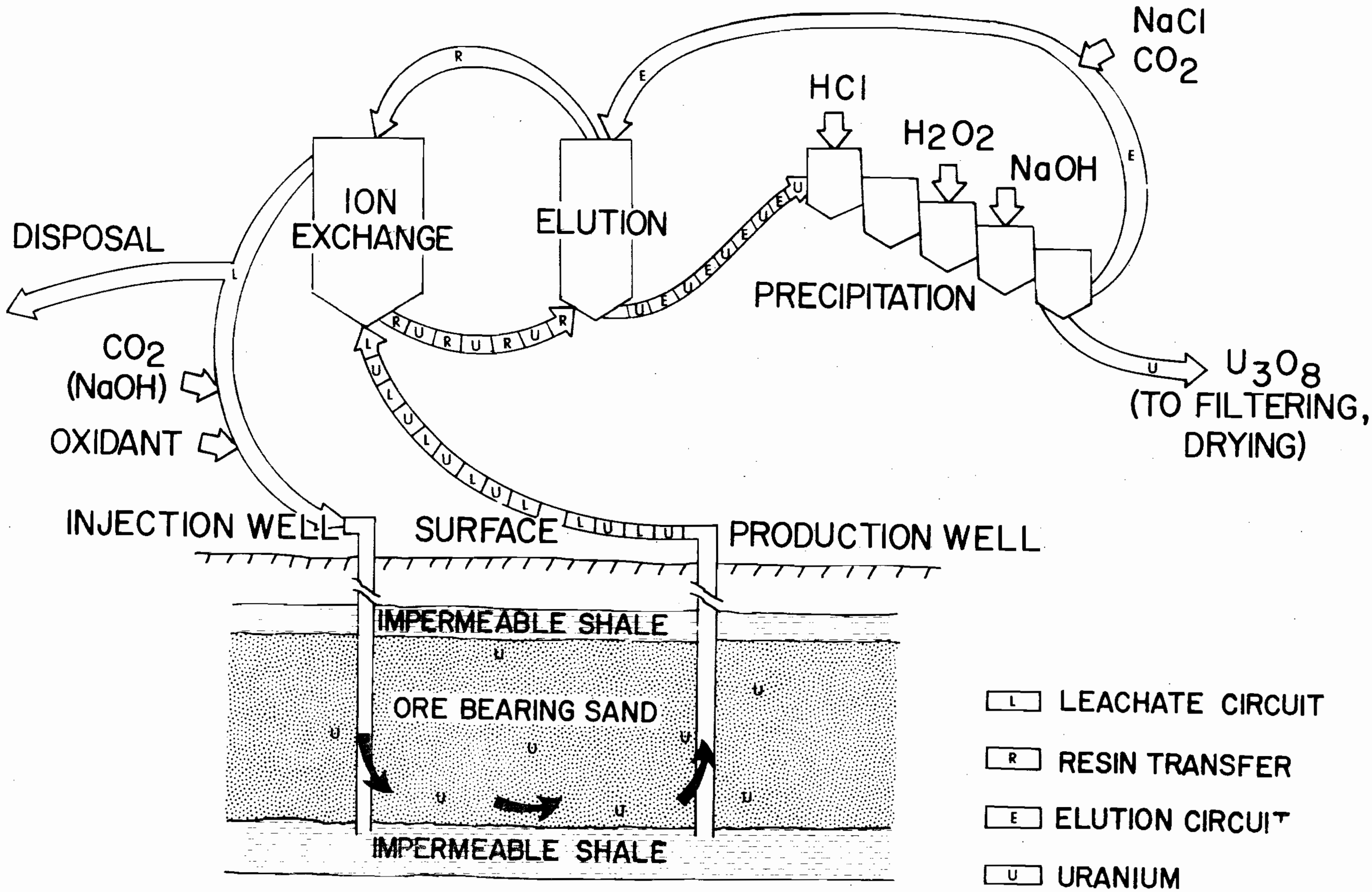
Open-pit mining is the most practical and economical method of ore extraction in relatively shallow, low-grade deposits where depths to ore range from ground level to less than 500 ft. Open-pit uranium mining methods have been employed in New Mexico at a number of localities in the past, primarily at the Jackpile-Paquate complex in the Laguna district and peripheral, associated occurrences in the Jackpile Sandstone, and on the Todilto Bench around Haystack Butte in the Ambrosia Lake district. Geologic factors that determine whether a deposit may be mined using open-pit methods include shallow depth of ore, low-grade irregularly shaped or distributed ore bodies and low stripping ratio, that is the thickness of spoil or waste as overburden that must be removed to gain access to a similar thickness of ore at depth. Open-pit methods also allow for a high degree of selectivity of both low-grade and relatively high-grade material.

At the Jackpile-Paguate, the stripping depths range from 50 to 250 ft, and stripping benches are established at 35-ft intervals at a slope of 3/4 to 1, excluding roads. The horizontal and vertical dimension of each stripping operation is known as a pushback, and mine economics are calculated on the lbs of U_3O_8 that may be expected to be recovered from the volume of ore stripped in each pushback operation. The sale value of the U_3O_8 is compared to the total production costs of the material in each pushback operation.

The open-pit technique at the Jackpile-Paquate mine has been described in detail by J.T. Wood, 1977, as follows:

"Drilling and blasting are two of the most critical operations at the mine. Drilling is accomplished with Chicago Pneumatic and Ingersol Rand truck-mounted rotary blast hole drills. Bit sizes are 63/4 and 73/8 inches in

Figure IV-2. Flow diagram showing a typical uranium in situ leaching process (Modified after Conine 1980).



diameter. The hole patterns range from 12 x 16 ft to 20 x 22 ft, with 10 to 5 ft of sub-level drilling. The Tres Hermanos Formation is composed of layers of shale, muddy sandstone, and hard mudstone. The layers of hard mudstone cause the most difficulty in the drilling and blasting operations. When the hard mudstone is located at the bottom of the bench, the softer shales blow off the top, leaving a hard toe. When the mudstone is near the top of the bench, the shales blow out, leaving large boulders of mudstone on top of the muck pile. Blasting is done with ANFO and cast boosters using 50-grain primacord down the hole and 30-grain primacord for trunk lines. All blasts are ignited with cap and safety fuse. Millisecond delays seperate sets of holes, whichever best suits the blasing pattern. Blasting to a free face produces uniform muck and keeps the muck pile betwwen a height of 15 to 20 ft for better loader performance.

Stripping equipment consists of four Dart D600 loaders with 15 cu. yd. buckets, two Caterpillar 992 loaders with 10 cu. yd. buckets, and one P & H-1600 electric shovel with a 6 cu. yd. bucket. Stripping material is transported by seventeen Euclid R50 trucks. The extended length of the Jackpile-Paguate ore deposits dictates the use of mobile loaders over the less mobile shovel. Caterpillar D9's push to the loaders when free blasting is not possible.

Waste material is dumped into mined-out areas of the pit to minimize haul distance and to aid in reclamation. Dumps established outside the pit area are restricted to 50-ft lifts with a 25 to 50-ft terrace between lifts to duplicate the mesa topography of the surrounding country. Vegetation is established after stockpiled topsoil is distribu ted over dump slopes and surfaces.

After the overburden is removed, the area to be mined is drilled on a 25-ft square pattern with small diameter bits. The holes are probed with a scintillator to more accurately determine the exact outline of the ore areas. The results are plotted on maps with 10-ft elevation differentials to be used by an ore grade controller to control the actual mining operation. The area to be mined is divided into working panels that are ripped to a depth of 24 inches by a D9 Caterpillar. To maintain minimum dilution, 24 inches is the maximum depth ripped. Each panel is probed, and areas of high-grade ore, low-grade ore, and waste are outlined with 24-inch lathes and colored ribbon. A sketch of each panel is given to the mining loader operator.

Mining equipment consists of five D9 Caterpillar tractors, five 988 Caterpillar loaders, and twenty Euclid R20 trucks. The 988 loader with a 6½ cu. yd. bucket is the largest machine capable of working the smaller ore areas. Dilution is kept to a minimum by removing waste first, low-grade second, and high-grade last. Loader trucks pass under a truck scanner, which is a steel frame with one to four scintillation detectors. Four of these are now in operation at the Jackpile-Paguate mines. One of the first truck scanners used by the industry was installed at the Jackpile mine. It has six scintillation detectors positioned in such a manner as to completely scan the load. Thousands of scanned truck loads of ore have shown that two detectors are suffucient, and any more are superficial. Each truck is scanned for 30 seconds and sent to the appropriate stockpile. The accuracy of the installation is 0.01 percent U_3O_8. Due to the complexities of the ore bodies, a predetermined grade of ore cannot be mined each and every day. Through the use of a stockpile reclaim system, one to twelve weeks capacity of mill grade material is maintained.

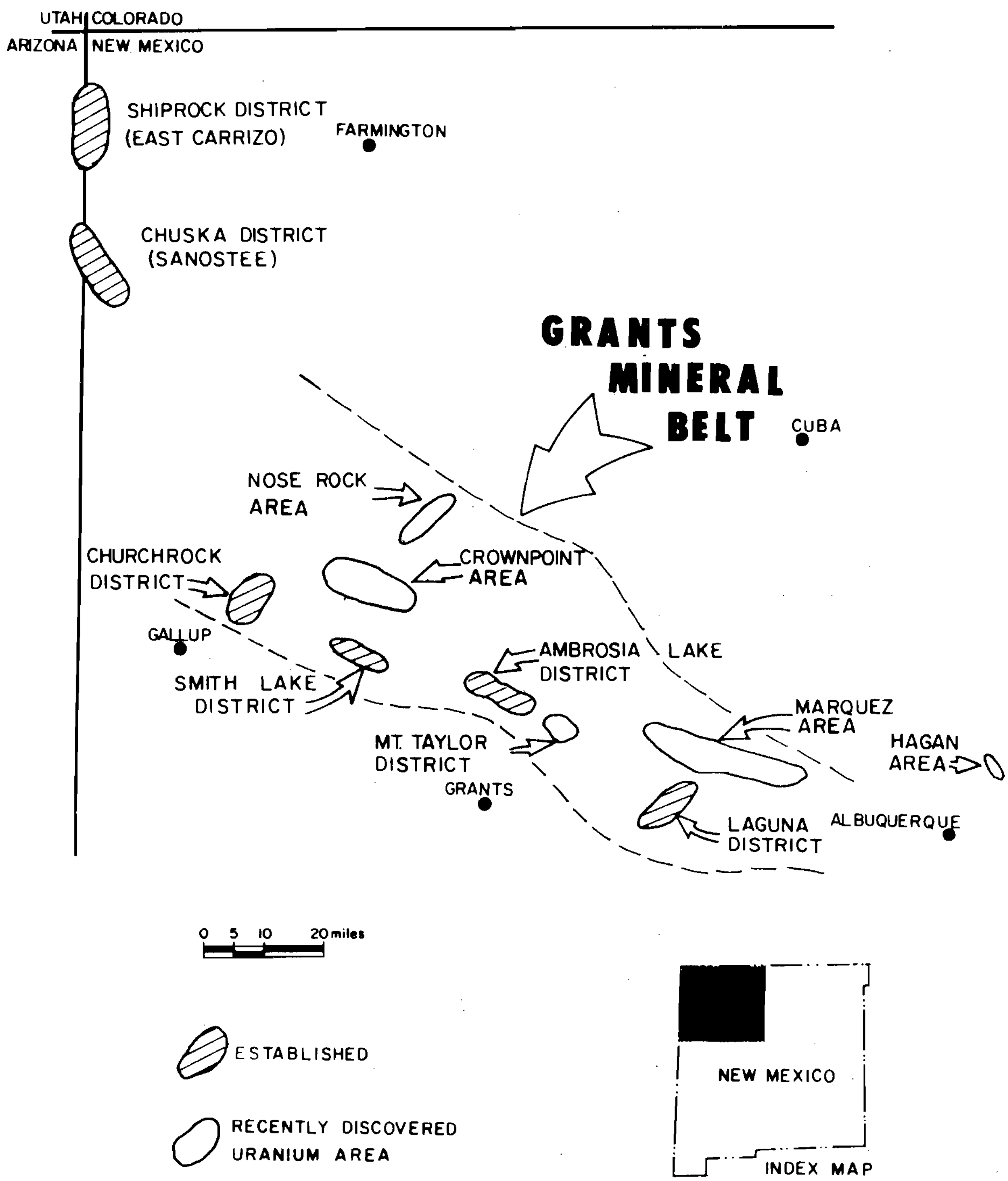
Ore is shipped from the mine by rail fifty miles to the Anaconda mill at Bluewater, New Mexico, six days a week. Ore is loaded by Caterpillar 988 loaders into R20 trucks from designated stockpiles, and hauled to the crusher. The ore is crushed by a 42 x 48-inch jaw crusher and moved by a 48-inch conveyor belt to the railroad car being loaded. As the ore moves over the conveyor belt, it is scanned again to insure control of the grade of ore loaded into each railroad car. The loading system is automatically controlled by a weightometer to avoid overloading of railroad cars. This system will permit tonnages shipped within 1 percent and grades within 0.0005 percent."

Open-pit methods are expected to be employed less frequently in New Mexico in the future than in the past as newer deposits are developed at ever increasing depths either through underground methods or in situ leach methods.

Mines and Mining Districts

Several established mining districts comprise the uranium-producing regions within the state. Because of recent discoveries in areas that have not been traditionally included within the older established districts, it will become necessary to better define the new as well as the old districts (Figure IV-3).

Figure IV-3. Map showing established mining districts, the Grants Mineral Belt and recently discovered uranium areas in northwestern New Mexico (New Mexico Bureau of Geology).



The Shiprock district, which begins at the northwestern corner of the state near the Four Corners, is the oldest uranium-producing area in the state. There are currently no active uranium mines in the Shiprock district. To the south, in the Sanostee area, is the Chuska mining district, which boasts the only currently active uranium mine in New Mexico outside of the Grants Mineral Belt.

South of the Chuska district is the westernmost district of the Grants Mineral Belt, the Gallup or Church Rock district. The Church Rock mines of United Nuclear Corporation and Kerr-McGee are located in this area. Further to the east, the Smith Lake or Blackjack district is located north of Thoreau. The Poison Canyon mines of Mariano Lake, the Ruby mines, and the Westranch mine are in this district.

One of the newer areas, the Crownpoint area, is located north from Smith Lake. The Crownpoint projects of Conoco and Mobil, the Nose Rock project of Phillips, the United Nuclear Corporation-Tennessee Valley Authority project at Dalton Pass and Canyon, and the Borrego Pass project of Conoco are all located within this large and, as yet, poorly defined region.

The Hospah-West Largo area, another relatively new area of interest, is located east of the Crownpoint area.

The famous Ambrosia Lake district lies south of the Hospah-West Largo area and southeast of Smith Lake. This district actually embraces several distinctly different deposits, including those in the Westwater, Brushy Basin, Poison Canyon, and Todilto Limestone. The Ambrosia Lake area contains two of the oldest continually active mines, the Haystack and the Poison Canyon mines. The extinct volcano, known as Mount Taylor, is located east of Ambrosia Lake. Because of the large complex of deposits such as Gulf's Mount Taylor project, the area may become known as a district in itself, once into full production.

The Laguna district, where the famous "Jackpile" deposits are located such as Jackpile-Paguate, Saint Anthony and L-Bar (JJ No. 1) is to the southeast of Mount Taylor. Recently discovered Westwater deposits to the northeast of Laguna near Marquez, at Rio Puerco, and at Bernabe deserve to be distinguished from the Laguna deposits, and some workers are calling this area Marquez. To date, however, there are no producing Westwater mines in the Marquez area.

Several active mines that were in production during 1978 and 1979 have been closed or are temporarily inactive.

Active Mines

Non-confidential data on active mines have been assembled and are presented in Table IV-2. These are discussed for the appropriate mines in the following section.

Anaconda's Jackpile-Paguate mine at Laguna consist of two seperate ore bodies in the uppermost Morrison or Jackpile Sandstone of economic usage. The Jackpile complex is approximately 1½ miles long and over 5 miles wide while the Paguate is 2 miles long and several hundred feet wide. The two combined deposits are mined from four contiguous pits that when combined constitute the world's largest open-pit uranium operation. Since the open-pit operation was begun in 1952, the pit area has expanded to more than 660 acres with overburden and low-grade stockpiles covering about 1,000 acres. In July 1980, Anaconda announced a plan to phase out the open-pit operation beginning in the summer of 1980. Reclamation plans are presently being formulated for the pit areas. Tonnages presently being shipped from the mine and stockpiles are averaging 0.08 to 0.09 percent U_3O_8 (1.6 to 1.8 lbs per ton) (U.S. Geological Survey, June 1980).

In 1976, the ore was blended to 0.23 percent U_3O_8 (4.6 lbs per ton) for shipment by unit trains to the Bluewater mill. In 1977, it was projected that 499,000 tons of ore averaging 0.19 percent U_3O_8 would be mined from the pits. Exact production is proprietary information and cannot be published. For 1978, projections were for 768,000 tons of ore averaging 0.14 percent U_3O_8. Between 1965 and 1975, the ratio of ore to low-grade and waste averaged 1:6.

The P10 decline produces about 1,000 tons of ore per day. The ore is crushed and then carried to the surface on a conveyor belt. Average grade varies and is expected to decrease from 0.34 percent U_3O_8 (6.8 lbs per ton) in 1977 to about 0.15 percent (3 lbs per ton) in 1980. The PW2/3 underground mine produced about 50 tons per day when it was in operation, but the mine is presently closed. The Jackpile-Paguate deposits are reviewed by Beck and others (1980).

Cobb Nuclear operates three mines in the Grants Mineral Belt. Two of these mines are located at Ambrosia Lake, the Section 14 mine and the Section 12 mines, both in T. 14N., R. 10W. The third mine is the Westranch mine in Section 32, T. 15N., R. 11W. near Casamera Lake in the western part of the Ambrosia Lake district. The Section 12 mine is connected to the Dysart No.2, formerly operated by Kermac, and the Westranch is the old Moe mine (Hilpert,

Table IV-2. Active uranium mines in New Mexico as of December 1, 1980. Abbreviations used include ID (inside diameter), MR & P (modified room and pillar), MWR (mine water recirculation), and VS (vertical shaft) (New Mexico Mining and Minerals Division).

NAME	COMPANY	LOCATION	TYPE ENTRY	MINING TECHNIQUE	MAXIMUM DEPTH (ft)	NO. EXHAUST VENTS	AIR DISCHARGE (ACFM)	MINE WATER PUMPED OUT (GPM)	CURRENT STATUS OR OTHER INFORMATION
Jackpile-Paguate	Anaconda	T.11N.,R.5W. Sec.33,34,35 10N.,R.5W.	Open-pit & underground	Pushback/ strip & MR&P	100 - 350	-	-	-	World's largest open-pit uranium mine with about 3000 ac. of pit area ; production to end in 1981 but stockpiled ore will be shipped thru 1982.
P-10	Anaconda	T.10N.,R.5W. Sec.4	9' x 16' decline @ 13% grade	MR & P	450	7	335,000	95	To be mined until 1983. May drift from P-10 decline to P-15 ore body.
Sec.12	Cobb	T.14N.,R.10W. Sec.12	Vert.shaft 14' dia.	MR & P	694	2	100,000	Dry	Connects to Dysart No.2 Returned to Cobb from Koppen 4/80.
Sec.14	Cobb	T.14N.,R.10W. Sec.14	Vert.shaft	MR & P	360	3	68,000	-	Redevelopment for MR & P
Westranch	Cobb	T.15N.,R.11W. Sec.32	Decline @ 20° grade	MR & P	200	1	8,000	Dry	Old Mo Mine; portal in Sec.33 inactive shaft.
Mariano Lake	Gulf	T.15N.,R.14W Sec.12	Vert.shaft 5' x 16'	Pillar retreat	519	2	85,000	200-230	Radmark system of dry backfill used. Reserves to be depleted by 1982.
Mt. Taylor	Gulf	T.13N.,R.8W. Sec.24	V.S. (2) 14'& 24' diameter	MR & P trackless & track	3,300	1	250,000	4,000	Drift development and production.
Sec.19	Kerr-McGee	T.14N.,R.9W.	-	MR & P	779	6	205,000	*	
Sec.22	Kerr-McGee	T.14N.,R.10W. Sec.22	Vert.shaft	-	827	-	-	*	MWR only
Sec.30	Kerr-McGee	T.14N.,R.9W. Sec.30	Vert.shaft	MR & P	750	13	413,000	*	
Sec.30 W	Kerr-McGee	T.14N.,R.9W. Sec.30	Vert.shaft 12' 6" ID	MR & P	810	6	364,000	*	
Sec.33	Kerr-McGee	T.14N.,R.9W Sec.33	Vert.shaft	-	848	-	-	*	MWR only
Sec.35	Kerr-McGee	T.14N.,R.9W. Sec.35	Vert.shaft 14' dia.	MR & P	1,394	6	414,000	1,450-1,600	

* The total volume pumped from these mines, plus two other Kerr-McGee mines, is 2,500 gpm.

Table IV-2. (continued)

NAME	COMPANY	LOCATION	TYPE ENTRY	MINING TECHNIQUE	MAXIMUM DEPTH (ft)	NO. EXHAUST VENTS	AIR DISCHARGE (ACFM)	MINE WATER PUMPED OUT (GPM)	CURRENT STATUS OR OTHER INFORMATION
Sec.36	Kerr-McGee	T.14N.,R.9W. Sec.36	Vert.shaft 14' dia.	MR & P	1,473	4	228,000	1,450-1,600	Old Phillips Cliffside Mine
Churchrock #1	Kerr-McGee	T.17N.,R16W. Sec.35	Vert.shaft 14' dia.	R & P	1,851	4	406,000	3,800 Total	Connects to IE mine
Churchrock #1 East	Kerr-McGee	T.17N.,R.16W. Sec.35	Vert.shaft 12' dia.	R & P	1,529	-	-		
Hope	Ranchers Ex.& Dev.	T.13N.,R.9W. Sec.19	Vert.shaft 8' dia.	-	400	-	-	50	Minimum of 6 months production life.
Johnny M	Ranchers Ex.& Dev.	T.13N.,R.8W Sec.7 &#8	Vert.shaft	-	1,380	2	140,000	900-1,100	Utilizing sand slurry backfill.
Enos Johnson	R. Williams Mining Co.	9 mi.W of Sanostee	2 adits - Dbl/entry	MR & P	-	1	60,000	Dry	Only producing mine outside GMB.
JJ #1	Sohio-Reserve	T.11N.,R.5W. Sec.13	Vert.shaft 14' dia.	-	672	7	270,000	100	Track and trackless sublevel stoping.
Haystack	Todilto Ex.& Dev.	T.13N.,R.10W. Sec.19	Adit & Pits	MR & P & strip	157	2	41,000	Dry	9' x 9' drifts underground
Sec.13	UN-HP	T.14N.,R.10W. Sec.13	Vert.shaft 12' 8" dia.	MR & P	618	2	232,000	Dry	
Sec.15	UN-HP	T.13N.,R.10W. Sec.15	Vert.shaft & decline	MR & P	623	4	251,000	Dry	
Sec.23	UN-HP	T.14N.,R.10W. Sec.23	Vert.shaft 14' dia.	MR & P	850	12	500,000	400-600*	
Sec.25	UN-HP	T.14N.,R.10W. Sec.25	Vert.shaft 11' x 14'	MR & P	811	7	445,000		
N.E.Church-rock	United Nuclear	T.17N.,R.16W. Sec.35	V.S. (2) 12' - 14' dia.	-	1,700	5	667,000	1,200	Sand backfill using mill tailings.
Old Churchrock	United Nuclear	T.17N.,R.16W. Sec.17	-	-	813	-	-	225-	Mine re-entry, different headframe with new hoist.
Ruby 1 & 2	Western Nuclear	T.15N.,R.13W &14W. Sec.21, 27	Decline	-	360	-	-	Dry	

* Includes Section 32.

1969). Cobb's Spencer shaft was being operated by Koppen Mining and Construction until April 1980, at which time the property was returned to Cobb.

With the completion of the production and ventilation shafts at Mount Taylor, Gulf Mineral Resources has two active mining projects including the Mount Taylor mine and the Mariano Lake mine.

Gulf Mineral Resources began production at their Mariano Lake mine near Smith Lake in October 1977. The mine is located on Indian-allotted land. Mining is expected to continue until 1982 when reserves are depleted. In-place pre-mining reserves are estimated to be 3.94 million lbs. Of these reserves, approximately 3.0 million lbs will probably be recovered. In June 1980, production was averaging about 500 tons per day, an increase from the November 1979 rate of 300-500 tons per day.

The ore is located in the basal Brushy Basin Member of the Morrison Formation in a mineralized trend that runs along a synclinal axis. The deposit is a roll-type and occurs along an iron-sulfur redox interface (Place and others, 1980). Several other nearby mines are located in this trend. The mined ore averages 0.2 percent U_3O_8 (4 lb per ton) with a cutoff of 0.07 percent. Some material averaging as low as 0.05 percent U_3O_8, however, is also shipped. Material running from 0.02 to 0.05 percent U_3O_8 is stockpiled, and material less than 0.02 percent U_3O_8 is place on the waste bench. Ore from the mine is shipped by truck (part of the way using a private haul road) to Kerr-McGee's Ambrosia Lake mill. All production from this mine has already been sold by contract to Florida Power.

In June 1980, the dewatering rate was approximately 157 gpm (gallons per minute), or a slight decrease from the November 1979 rate of 190 gpm. In one small area of the mine, it is possible that collapse occurred through the Brushy Basin into the overlying Dakota when the pillars were pulled. A very small amount of water from the Dakota, therefore, may be included in the discharge.

The discharge water is sent to a series of lined settling ponds. An IX (ion exchange) facility removes uranium (56 mg/1) from the clarified liquid. The uranium is stripped from the IX beads and the uranium concentrate solution is shipped by tanker truck to Kerr-McGee's mill. The discharge from the IX has $BaCl_2$ (barium chloride) added and goes through further settling ponds for Ra-226 removal before discharge. The precipitated radium-bearing sludge will be sent to a tailings pile when the mine ceases operation.

A small part of the Mariano Lake mine is undergoing dry or pneumatic sand backfilling. Haulage development waste and limestone chips are being mixed together and pneumatically injected by a Radmark system into the desired area of the mine. While bulkheads do not have to be as sturdy as with hydraulic backfill, costs are greater because of the requirements of the necessary diesel-powered compressor equipment. The Radmark system began operation in January 1980, and about 200-300 tons per day are presently injected into the mine. Other mining techniques such as haulage below the ore body and use of slushers and loaders are similar to that presently in use in the Ambrosia Lake and are are discussed elsewhere in this report.

In June 1980, there were 93 hourly and 22 salaried employees. Approximately 70 percent of the employees in the Mariano Lake mine are Navajos. When Mariano Lake closes, all employees will be given the opportunity to work at Mount Taylor.

Beginning in 1971, Gulf began a uranium exploration program on the western slope of Mount Taylor. This program, which included drilling and coring in some 600 holes from more than 3,500 ft below the surface, helped to define a complex of ore bodies located in the upper and lower Westwater along a 6-mile trend containing a minimum of 124 million lbs of U_3O_8. Gulf has now obtained control of most of the mineral rights in this 6-mile area.

In 1974, shaft sinking by Harrison-Western Corporation began on two shafts 600 ft apart in Section 24, T. 13N., R. 8W. One shaft, the production shaft, is 24 ft in diameter and concrete lined with a 220-ft high headframe, while the service shaft (for employees) is 14 ft in diameter and concrete lined. Each shaft is served by two hoists. The production shaft has a double-drum 2,500 hp Nordberg unit. These shafts were completed to the final depth of 3,300 ft in 1979. Total cost of shaft construction was approximately $200 million. In addition to the traditional drilling, blasting, mucking, hoisting, and grouting, dewatering wells were constructed around the shafts and completed into each of the several aquifers in order to depressurize zones prior to shaft sinking.

By July 1980, most stations were complete and work on haulageways and development stoping areas was underway. One of the major tasks is to drain the working areas as rapidly as possible, since the incoming water temperature is 128°F. Once the areas are dewatered, temperature control becomes much easier. Ice vests, water shields for the long-hole drillers, refrigeration units, large air flows, and air conditioning traincabs are all used to allow safe mining to proceed.

Three main levels are being developed in the Mount Taylor mine. The upper level, 3,100 ft below the surface, is the ore (stoping) level. The haulage level is below this level, at 3,200 ft. Ore is mined above the haulage level and dropped downward through an ore pass into a railcar, which carries the ore to the production shaft for hoisting. Twelve tons of ore can be hoisted at one time from the production shaft. The haulage level also carries incoming fresh air from the downcast service shaft. A drainage/exhaust level is located about 15 ft below the haulage level and is used to drain water to the main sump level and to take return exhaust air to the upcast production shaft. The lowest level is the 3,300 ft sump level which handles all drainage water. The water is pumped to the surface by pump stations at 3,200 and 1,600 ft in the service shaft. The 3,300 ft level can act as a large sump in case of pump failure. Presently about 5,200 gpm is being pumped; however, the mine is actually making only about 4,000 gpm because of water reuse in the mine.

The rock has proven to be very competent. The main passageways are being constructed to a size of 10 ft-by-10 ft. An experimental mining program has been completed, and an undisclosed quantity of ore had been toll milled by June 1980.

Gulf personnel have indicated that new mining techniques have and will be developed for the Mount Taylor mine. For example, much more mechanized mining will be used. An AEC miner has been modified for use in the Westwater Sandstone. Consideration is being given to slurrying haulage development waste into mined out areas as a means of ground control and waste disposal.

Target ore production is 4,000 tons per day yielding between 7-8 million lbs. U_3O_8 per year. This production rate will be slowly phased in as it will depend on such diverse parameters as management policy, the time when the mill reaches completion, toll contracts, and market committments.

Average ore grade is expected to run about 0.3 percent U_3O_8 (6 lbs per ton). Cutoff has been tentatively set as 6 ft at 0.10 percent U_3O_8. The uranium occurs as coffinite and appears to be in secular equilibrium with its daughters. The Mount Taylor uranium deposit has been described by Riese and Brookins (1980).

The ore is somewhat difficult to reach. Longer retention time, higher leaching temperatures and pressures, and lower pH in the leaching tanks are various ways which might be use to increase recovery. The ratio of uranium to molybdenum runs about 15.1 in the ore, and a molybdenum recovery circuit may be planned.

The water first coming into the mine's central sump area undergoes some settling in this sump. Once the water is pumped to the surface, it goes through several baffled, lined settling ponds. An ion exchange facility has been completed at the site but is presently not in use. The water has $BaCl_2$ (for radium precipitation) and acid (pH adjustment) added before going through the final settling ponds. From the final settling pond, the water is transported in a 24-inch pipe to the San Lucas Dam area for discharge. Final dewatering rates as the mine develops could reach 5,000-10,000 gpm.

Once the mine is in full production, mine waste will probably be about 600 tons per day. This waste will be used either as backfill or place on the mine's waste bench area near the mine.

Construction of a third shaft, (approximately 4,700 ft deep due to a higher collar elevation than the present shafts) is being considered as a vent shaft for the mine as the mine develops outward. A fourth shaft may also be necessary.

There are 7,500 kilovolt-amphere (Kva) of standby generator (5,000 kw jet turbine and 2,500-kw diesel) equipment available in case of loss of electric power. A 20,000 Kva substation serves the mine complex. Power is supplied by Public Service Company of New Mexico.

Approximately 530 persons including both Gulf and Harrison-Western personnel are presently employed at the site. Between 750 and 1,000 employees will be working at the mine-mill project when it is in full production.

Gulf has announced plans to build a mill near the mine to process the Mount Taylor ore. The time frame for construction of this mill is dependent upon receiving state licensing and permit approval, company policy, marketing contracts, and other considerations. Until the mill is completed, ore will probably be tolled at nearby mills. Tolling would probably result in lower U_3O_8 recovery from the ore than ultimately planned by Gulf.

At the present time, Gulf has no marketing contracts for its uranium production from Mount Taylor; however, it is expected that contracts will be obtained soon. Because of the large reserves, extensive mine production capacity, and rather high-grade ore, the Mount Taylor mine is expected to produce a major portion of New Mexico's uranium in the coming years.

Homestake Mining Company, in partnership with UNC (United Nuclear Corporation), operates five uranium properties in the Ambrosia Lake district. All properties are developed in the Westwater Canyon Sandstone Member of the Morrison Formation. The active mines are the Section 13, 15, 23, and 25 mines. The Section 32 mine is idle except for recovery of uranium through mine-water recirculation. A comparison of fiscal 1979 and 1980 production from UNC-Homestake partnership mining operations can be seen in the preceeding discussion on United Nuclear Corporation. Homestake owns 30 percent interest in all UNC-Homestake partnership operations.

Western Nuclear, a subsidiary of Phelps-Dodge, mines the Ruby Wells deposits at Mariano Lake in the Smith Lake district. The complex consists of four separate mining developments, the Ruby No.1, No.2, No.3, and No.4. The Ruby No.1 and No.2 may be considered one mine since they are connected and entered through the same decline. The Ruby No.3 and No.4, currently under development, will also utilize a common decline for entry and will eventually connect by drifts as mining progresses. All Ruby deposits are in the Poison Canyon Sandstone tongue of economic usage at the Westwater-Brushy Basin contact. The deposits lie along the same synclinal axis as the adjacent Mariano Lake, Mac, and Blackjack deposits (the latter two are inactive). All of the Ruby mines are on the same stratigraphic and structural level. Ristorcelli (1980) has discussed the geology of the Ruby Wells deposits in the Smith Lake district.

The Ruby No.1 and No.2 are reached by the same decline. All pillars have been pulled in Ruby No.1 and retreat completed, except that some barrier pillars have been left to insure stability in the decline area and in the 3,000 ft-long drift over to the Ruby No.2. Total production from the Ruby No.1, which began production in 1976, has been approximately 2 million lbs U_3O_8. Total recovery of ore in place to the desired cutoff has been estimated to be about 85 percent. Ore grade has averaged 0.17 percent U_3O_8 (3.4 lbs per ton). Mine development and ore recovery are now (June 1980) taking place in Ruby No.2 with the first production having been achieved in March 1980.

Production from Ruby No.2 averages 400-500 tons per day. The average ore grade is approximately 0.17 percent U_3O_8 (3.4 lbs per ton) with a cutoff grade of 0.05 percent U_3O_8. Ore grades higher than 0.03 percent but less than 0.05

percent U_3O_8 are stored for later blending. The mine uses rubber-tired vehicles and slushers. It is expected that pillars will be pulled in the Ruby No.2 using the same procedure as in Ruby No.1. Caving within the overlying Brushy Basin can extend up to the Dakota Sandstone and occurs so rapidly that pillars are not shot until after the ore has been quickly slushed out. No surface subsidence has been detected.

The ore is trucked via Western Nuclear's private haulage road to Kerr-McGee's Ambrosia Lake mill some 32 miles away. Mining will be completed in 1981 at the Ruby No.2 when ore reserves are exhausted.

The 2,050-ft long decline serving Ruby No.3 was completed in the spring of 1980. Drifting to intersect the vent shafts and the ore body is in progress with mining of ore from Ruby No.3 scheduled for the fall of 1980. When in full production, Ruby No.3 will produce approximately 800 tons per day. Ruby No.4 will also use the Ruby No.3 decline. Mining of these two mines should be completed in 5 years. Production during these years will probably be somewhat more than the present Ruby No.2 production. All mines are virtually dry, producing less than a gallon of water per minute.

Total employment at the Ruby mines is presently about 78 of which 45 percent are Navajo.

Todilto Exploration and Development opened its new Piedra Triste mine in Section 30, T. 13N., R. 9W. in 1979. Like the Haystack mine also operated by Todilto, the Piedra Triste is a Todilto Limestone deposit worked initially by open-pit methods and finally developed as an underground mine. In October 1980, the Piedra Triste was closed due to low spot market prices, high production costs, and unfavorable severance tax rates. The nearby Haystack is one of the oldest continuously operated uranium mines in New Mexico, having been developed as a result of the 1950 discovery by Paddy Martinez at the base of the butte for which the deposit is named. Todilto uranium deposits are discussed by Rawson (1980).

UNC Resources is the holding company for United Nuclear Corporation which normally operates six mines in the Grants Mineral Belt. Beginning at the west end of the belt, UNC operates both the NE Church Rock mine and the Old Church Rock mine which has been recently reactivated. Further east in the Ambrosia Lake district, UNC operates three mines, currently idle: the Anne Lee, the Sandstone, and the Section 27 mines. All of these mines are underground and produce from the Westwater, although the Old Church Rock produced in the past from the Dakota as well as the Morrison. Leaching operations are continuing at the three Ambrosia Lake mines during their closure. The Saint Anthony mine in the Laguna district is an old underground mine that was later developed into a joint underground and pit operation. Production is from the Jackpile sandstone in the Morrison Formation. Currently operating on a reduced schedule, the Saint Anthony shaft is idle and production is only from stockpiles in the open-pit area. The geology and ore trends of the Saint Anthony underground mine are discussed by Baird and others (1980).

A comparison of fiscal 1979-1980 UNC uranium production by selected mine has been made public (UNC Annual Report, 1980) and is shown below with production units in lbs U_3O_8 concentrate.

	1979	1980
Church Rock mine	1,515,000	1,196,000
Ambrosia Lake mines (Anne Lee, Sandstone, Sec.25 & Sec.27)	424,000	393,000
St. Anthony mine	559,000	575,000
United Nuclear-Homestake Partners	1,098,000	1,147,000
Other[1]	275,000	288,000
	3,871,000	3,599,000

[1] includes purchased ore, by-product recovery and production by ion exchange from mine waters.

Kerr-McGee's total uranium operations include one mine at Church Rock, the Church Rock No.1 (connects to No.1 east) and nine mines at Ambrosia Lake. Four of the Ambrosia Lake mines, the Sections 17, 22, 24, and 33 mines, are producing uranium through mine-water recirculation only. The other Ambrosia Lake mines include the Sections 19, 30, 30W, 35, and 36 mines. All ore bodies are in the Westwater Canyon Sandstone Member of the Morrison Formation at depths ranging from 750 to 1,600 ft at Church Rock. Ore grades are not available for publication.

In addition to their Church Rock and Ambrosia Lake mines, Kerr-McGee has plans to develop a new mine to be called the Lee mine at Roca Honda in Section 17, T. 13N., R. 8W. The shaft collar is expected to be completed by the end of the summer of 1980. The shaft itself will be a 15-ft-diameter concrete-lined shaft to a depth of about 1,650 ft in the Westwater. Although the company has no exact time frame for the completion of the property, lease rights must be maintained. The lifespan is expected to be 15 years, and when at peak production, the mine should employ some 225 people.

The Rio Puerco mine of Kerr-McGee was closed shortly after it had gone into production in late 1979. Uncertainties in the uranium industry coupled with low market prices for uranium, high production costs, and unfavorable taxation were cited as major factors contributing to their decision to discontinue operations at Rio Puerco. In addition, the excessive distance from the mine to the Kerr-McGee mill at Ambrosia Lake may have been an additional economic consideration at the time the mine was closed.

By mid-year 1980, the Flea/Doris Extension mine operated by M & M Mining in Sections 20 and 21, T. 31N., R. 9W., was idle. A new decline has been developed at the backside of the Doris extension and drifts connect to the Flea mine. The ore, partly controlled by a cylindrical collapse structure (Hilpert, 1969) is within the Poison Canyon sandstone at the Westwater-Brushy Basin contact.

Ranchers Exploration and Development has two mines under joint operation, both at Ambrosia Lake. The Hope mine is a Todilto Limestone deposit which is worked underground, and the Johnny M mine is in the Westwater. Chaco Energy is a joint partner at the Hope mine.

The Johnny M is a joint venture with HNG Oil Company, a subsidiary of Houston Natural Gas. It is the largest operation of the two mines, having produced 1.5 million lbs U_3O_8 in 1978 and expected to reach 3 million lbs by late 1980 (Albuquerque Journal, March 11, 1979) as the mine's northwest ore body comes into full production. Forward sales contracts of uranium have shielded the Johnny M somewhat from the softening uranium market. In November 1979, the company announced a significant supply contract with Taiwan Power Company of 2 million lbs U_3O_8 to be delivered from the Johnny M beginning in early 1981. Gulf States Utilities of Beaumont, Texas purchased the first 3 million lbs of uranium oxide from the Johnny M (Ranchers news release, November 9, 1979).

At the Johhny M, ore occurs at depths of about 1,400 ft and averages about 0.25 percent uranium oxide in three separate deposits in Section 7, T13N., R8W and a single deposit in the eastern half of Section 18 which was acquired from UNC in 1972. The Johnny M deposit is discussed in further detail by Fitch (1980) and Falkowski (1980).

The only currently productive mine in New Mexico beyond the limits of the Grants Mineral Belt is the Enos Johnson mine near Sanostee on the Navajo Indian Reservation operated by Ray Williams Mining Company. The deposit is in the Recapture Member of the Morrison Formation and has been mined intermittently since 1952.

The JJ No.1 mine operated by Sohio Petroleum Company is located on the L-Bar Ranch near Bibo. The L-Bar is jointly owned by Sohio and Reserve Oil and Minerals Corporation.

The sinking of the 665-ft-deep 14-ft-diameter concrete-lined shaft serving the JJ No.1 began on April 1, 1975 and was completed on September 1, 1975. The first ore was produced on July 26, 1976.

The ore bodies are located in the Jackpile sandstone. These are roughly tabular-shaped deposits and are found in general at three horizons. Ore grade runs from 0.1 to 0.4 percent U_3O_8 with an average grade of approximately 0.13 to 0.17 (2.6 to 3.4 lbs per ton) percent U_3O_8 (depending on mining area). Total reserves (including the pit and shaft mine yet to be developed) are estimated at 11 to 12 million lbs of U_3O_8. Jacobsen (1980) has discussed the geology and ore controls of the L-Bar deposits.

Ore removal is through the use of modified room and pillar techniques. The ore and waste are hauled to the central station by both tracked and tired vehicles where the material is placed in either the waste or ore trench. The skips are positioned into loading pockets and the material is slushed from the trench into the skip. There are two skips, each with a capacity of 3 tons. These are served by a hoist using a Canadian Ingersoll Rand 72 inch by 48 inch double drum driven by a 400 hp motor at 1,070 ft per minute. The skips in turn dump into a large steel bin (located in the 105-ft-high headframe) which has a capacity of 180 tons. From the bin, the material is loaded onto trucks for transport to the waste piles or mill.

Originally the haulage level was in the Brushy Basin below the level of all of the ore bodies; however, swelling of the clays in the Brushy Basin caused problems to develop in this haulage level. A level above the original level has therefore been developed in sandstone. Because some of the ore is below this level, declines will have to be developed into this stopping area and the ore moved up the ramps to the main skip loading area.

While the level above the original haulage was being developed, ore production lagged from the original target production of 1,500 tons per day. As of June 1980, however, production levels had increased to 1,000 tons per day. Mining personnel were optimistic that a level of production of 1,000 tons per day or more could be maintained.

It was originally estimated that about 400,000 tons of barren rock and 100,000 to 200,000 tons of low-grade material (less than 0.05 percent U_3O_8) would be produced over the lifetime of the mine.

Recently, part of the mine waste has been returned to the mine for backfill. Last year, mining personnel slurried sands (a total of 4,000 to 5,000 tons) back into mined out areas for ground control. It has been found, however, that slurried waste also works well, and 100 to 150 tons per day of waste are presently being slurried as backfill about twice each week. The total amount of backfill used over the mine's lifetime will depend on the ground conditions encountered during pillar pulling.

Approximately 230 persons are employed at the JJ No.1 mine. Mining personnel and equipment are transported into the mine using a Nordberg 78-inch by 66-inch single-drum hoist driven by a 250 hp motor at 470 ft per minute.

In June 1980, the mine was making approximately 60 gpm of water. This was a slight increase from November 1979 of 25 gpm. Water flow has always been less than was originally expected. For example, the original pumping system was designed for 250 gpm. The water is discharge into settling ponds from where it is pumped into the nearby mill circuit.

Two additional mines are expected to be developed by Sohio on the L-Bar property:

1) A pit-mine development beginning in 1983, which will start production in 1985 and produce through 1988, located in Section 25, T. 11N., R. 5W.

2) A shaft in Section 12, T. 11N., R. 5W. for which shaft construction will begin in 1986.

It is believed that this complex of Sohio mines will continue production until the late 1990's. At the present time, Sohio has fulfilled all contracts for yellowcake, and does not have a contract for future production.

Summary of Mine Closures by December 1980

As of December 1979, 42 mines were producing ore in New Mexico. Gulf Mineral Resources' Mount Taylor mine is included as an active mine although all ore mined is being stockpiled until mill facilities are complete. Fifteen active mines were out of operation by December 1980, reducing the total number of producing mines to 27. Of the 27 producing mines, many were operating on reduced shifts. At least eight mines were producing uranium through mine-water recirculation only, and several active mines were undergoing mine-water recirculation with minor production through IX (ion exchange) units. A list of idle uranium mines as of December 1980, is shown in Table IV-3.

Table IV-3. Idle uranium mines in New Mexico due to closures as of December 1, 1980 (New Mexico Bureau of Geology).

Mine	Location	Operator	1979 Production
P-9-2	Sec. 4-5-8, T. 10N., R. 5W.	Anaconda	No
PW 2/3	Sec. 33, T. 11N., R. 5W.	Anaconda	No
Sec. 10	Sec. 10, T. 14N., R. 10W.	Cobb	No
Spencer Shaft	Sec. 6 & 8, T. 13N., R. 9W.	Koppen	Yes
Rio Puerco	Sec. 18, T. 12N., R. 3W.	Kerr-McGee	Yes
Sec. 17	Sec. 17, T. 14N., R. 9W.	Kerr-McGee	Yes
Sec. 22	Sec. 22, T. 14N., R. 10W.	Kerr-McGee	Yes
Sec. 24	Sec. 24, T. 14N., R. 10W.	Kerr-McGee	Yes
Sec. 33	Sec. 33, T. 14N., R. 9W.	Kerr-McGee	Yes
Flea-Doris Ext.	Sec. 20 & 21, T. 13N., R. 9W.	M & M	Yes
Poison Canyon	Sec. 19, T. 13N., R. 9W.	Reserve	Yes
Piedra Triste	Sec. 30, T. 13N., R. 9W.	Todilto	Yes
Saint Anthony	Sec. 19 & 30, T. 11N., R. 4W.	UNC	Yes
Anne Lee	Sec. 28, T. 14N., R. 9W.	UNC	Yes
Sandstone	Sec. 34, T. 14N., R. 9W.	UNC	Yes
Sec. 27	Sec. 27, T. 14N., R. 9W.	UNC	Yes
Sec. 32	Sec. 32, T. 14N., R. 9W.	UN-HP	Yes

Ore production capacity, as calculated by the New Mexico Bureau of Geology, had declined by 7 percent during the first half of 1980 as result of mine closures (Hatchell, 1981). Year-end production levels would be made up by shipping and milling quantities of stockpiled ore.

Total employment in uranium mining as reported to the DOE in mid-1979 was 5,666 in New Mexico compared to 6,021 in 1978. Of this total, 1,843 were underground miners with an additional 1,836 service and support personnel;

338 were open-pit miners with an addtional 237 service and support personnel; 496 were technical personnel; 555 were supervisory personnel; and 361 were classified in other job categories.

New Mine Development

In addition to the 27 mines that were in operation as of December, 1980, several mining projects were in various stages of development or planning. Table IV-4 lists New Mexico uranium mines currently under development.

By early 1980, Gulf's Mount Taylor production mine shaft at San Mateo had been completed to the 3,300-ft sump level, and drifts to more than 200 ft beyond the shaft had produced up to 100,000 lbs of U_3O_8 from the Westwater Canyon ore bodies. All production to date has been stockpiled except for a minor amount that was shipped for metallurgical and milling tests. The ore mineralogy is principally coffinite and averages about 0.30 percent U_3O_8 (6 lbs per ton) with a uranium/molybdenum ratio of 15:1. Gulf considers 6 ft at 0.10 percent to be their economic cutoff. Production will be from ore pods within both the upper and lower Westwater Canyon sandstone that hosts the complex of deposits which is estimated to contain in excess of 100 million lbs of U_3O_8. The life of the mine is expected to be 20 years with a production shipping target date of 1982. Nominal production capacity of the mine when in full production is expected to be 4,500 tons per day. Gulf is still awaiting final licensing for a 5-million lb per year milling operation to be located in San Mateo.

The Mount Taylor deposit is regarded as the largest and deepest uranium deposit known in the United States.

Phillips Uranium Corporation continued to sink their 18-ft diameter production shaft at the Nose Rock No.1 mine northeast of Crownpoint. Work on the Nose Rock No.2 mine shaft was suspended in May 1980, with the company citing economic reasons due to delays in mill licensing and a slumping uranium market. By September 1980, the No.1 shaft had reached a depth of 2,600 ft toward a target depth of 3,200 ft by May 1982. The Nose Rock deposit is unique to the San Juan Basin of New Mexico in that the ore occurs in large roll-type deposits. All mineralization is within the upper and middle Westwater Canyon and is distributed along four horizons that total about 150 ft of thickness. When in full production, the 24-million-lb deposit connected by mine shafts No.1 and 2 should average 2,950 tons per day. The geology of Nose

Table IV-4. Mine projects under development in New Mexico as of June 1, 1980 (New Mexico Bureau of Geology).

Company	Mine	Location	Target Depth (ft)	Status
Amiran	Desiderio	Sec.26,T.13N.,R10W	-	Re-entry mining
Anaconda	H-1 Adit	Sec.4,T.10N.,R5W	-	Mine entry
Bokum	Marquez No.1	Sec.25,T.13N.,R.5W.	2,100	Sinking shaft
Kerr-McGee	Lee (Roca Honda)	Sec.17,T.13N.,R.8W.	1,675	Preparing shaft site
Kerr-McGee-TVA	Marquez	Sec. 23,T.13N.,R.5W.	2,200	Mine planning phase
Mobil	Crownpoint (in situ project)	Sec.9,T.17N.,R.13W.	2,000	Pilot operation
Mobil	Monument (in situ project)	Sec.28,T.17N.,R.12W.	2,000	Test drilling
Phillips	Nose Rock No.1	Sec.31,T.19N.,R.11W.	3,200	Sinking shaft
Union Carbide	Diamond Tail	Sec.16,T.13N.,R.6E.	10-400	Dev. drilling in progress
Western-Nuclear-Reserve	Ruby No.3 & 4	Sec.25&26,T.15N.,R.13W.	1,600	No.3 decline now completed
Western-Nuclear	Section 16	Sec.16,T.13N.,R.8W.	1,600	Development drilling
WMC-Conoco	Crownpoint	Sec.24,T.17N.,R.13W.	2,200	Sinking shaft

Rock orebodies are described by Clark (1980) and Nose Rock exploration techniques are discussed by Rhett (1980).

The Crownpoint Section 29 development mine shaft begun by the WMC-Conoco Mineral Corporation in mid-April 1980, had reached a depth of over 1,000 ft by mid-June 1980 and had reached the 2,200 ft production level by September. In order to minimize shaft sinking time, the shaft was drilled to total depth rather than employing the conventional blast-and-muck method. Now that the development shaft has been completed, the 3-ft diameter pilot hole for the main production shaft located at a distance of 100 ft will be connected to it by drifting. As the production shaft is drilled and blasted down through the pilot hole, muck and water will be hauled through the drift and pumped out of the adjoining development shaft. The company estimates that two full production years can be saved if the operation continues as planned. The Crownpoint deposit could be in production as early as 1982. Total recoverable reserves contain at least 10 million lbs of U_3O_8 and occur in four Westwater sandstone horizons. (Wentworth and others, 1980). Mill plans are as yet incomplete since the firm is in the process of evaluating potential sites.

Conoco has several discovery projects in various stages of development; however, mine plans are as yet incomplete. At the eastern extremity of the Grant Mineral Belt in Section 36, T. 12N., R. 2W., Conoco has a major uranium find in the area of Sandoval County known as the Bernabe-Montano. The deposit is in the Westwater Canyon Member of the Morrison Formation at depths ranging from about 1,700 ft to more than 1,900 ft. At least 10 million lbs of U_3O_8 reserves have been delineated on the property which is fully controlled by Conoco. Conoco has made shaft site studies and one amenability study at the property and is awaiting mining development which will depend primarily on the future recovery of the uranium market. No mill plans have as yet been filed. The Bernabe property is at the eastern edge of the Grants Mineral Belt at the juncture of the Rio Grande rift and the San Juan Basin (Kozusko and Saucier, 1980).

Conoco also has exploration development projects in progress at Borrego Pass and at Hosta Butte. The Borrego Pass deposit will probably be developed as a mine after the Crownpoint project is brought into production.

Dewatering problems and procedural delay in mill licensing continued to hamper development at the Bokum Resources Corporation Marquez mine through 1979. By February 1980, however, the firm's below-surface tailing disposal plant had been approved and a license was issued. At least two mineable uranium deposits occur at the Marquez property. The deepest deposit is located at approximately 2,100 ft and has recoverable reserves of 10.7 million lbs of U_3O_8. This deeper deposit is intercepted by the 2,100-ft-deep Marquez No.1 shaft. The Marquez No.2 ore body located at a depth of 1,600 ft has reserves of some 751,000 lbs of U_3O_8 and will be developed as market conditions and sales commitments allow. Livingston (1980) has discussed the geology and the development of the Marquez uranium deposit.

As discussed earlier, Kerr-McGee plans to develop a new mine in the Roca Honda area of Ambrosia Lake to be called the Lee mine. The production shaft site is located in Section 17, T. 13N., R. 8W. The collar for the 14-ft diameter concrete-lined shaft has been completed and other site work is progressing. A second production shaft was completed at Church Rock, and mine feasibility and planning studies are continuing at Marquez where the company is involved in a joint venture with the TVA (Tennessee Valley Authority).

By May 1980, Western Nuclear was retreat mining the Ruby No.2 deposit, which was opened by a 300-ft drift from the Ruby No.1 mine. The Ruby No.3 and Ruby No.4 inclines were completed in June 1980, and drift work should intersect the two ore bodies by October 1980. The Ruby No.3 will produce at about 800 tons per day when in full production. The Ruby ore bodies are in the Poison Canyon tongue of economic usage (uppermost Westwater). Western Nuclear anticipates that the Ruby deposits will be depleted within 5 years; meanwhile, exploration is continuing on their Section 16 ore body near Lee Ranch in the Ambrosia Lake district.

Another development during 1979 includes the apparently successful Mobil in situ leach project in Section 9, T. 7N., R. 13W., near Crownpoint. Although actual results have been withheld, a concentrated uranium slurry appears to have been produced by the pilot plant. The firm plans to apply to the EID (Environmental Improvement Division) for a permit to build a commercial-size, leach-solution facility planned for operation by 1982 with an ultimate capacity of about 2,000 tons per day. Mobil's Monument in situ project in Section 28, T. 17N., R. 12W., is in the planning stages with chemical testing planned to commenced in November 1980. Monument is located about 2 miles east of Crownpoint, where the mineralized Westwater host rock will be tested at depths of approximately 2,000 ft. A comparison of solution mining technology in New Mexico and south Texas is presented by Conine (1980).

Preliminary push-pull testing for a pilot in situ operation was successfully completed by UNC-Teton in June 1980, at Section 13, T. 1 6N., R. 17W. Teton plans to apply for a license to operate a pilot plant in the general vicinity of this testing in the late fall of 1980 and to proceed with additional development drilling and core testing. Potential production horizons at Section 13 lie at depths of 1,200 to 1,400 ft (Peterson, R.J., 1980). Other in situ leach projects that are planned and have been announced are listed in Chapter V, Milling.

AML Study

As part of a national inventory of abandoned coal mines, the Surface Mining and Reclamation Act of 1977 authorized the State of New Mexico to inventory and assemble data on all abandoned or inactive mine lands within the state. Although the act calls for primary emphasis to be directed on coal mines, uranium mine data was collected during the course of the inventory. All data collected will be utilized by the State of New Mexico in the development of AML (Abandoned Mine Lands) reclamation projects.

The Mining and Minerals Division of the New Mexico Energy and Minerals Department has been directed as the state agency to receive the federal AML funds. Under the direction of the Mining and Minerals Division , the New Mexico Bureau of Mines and Mineral Resources has been contracted to inventory and assess lands for AML reclamation under Phase I of a national inventory as well as under the state's cooperative planning agreement with the federal government. Other agencies, both state and federal, will become involved in subsequent phases of the AML project; meanwhile, the inventory of uranium sites that qualify under the terms of AML has been completed and will be released by EMD as part of a series of open-file reports in 1981. Thus far, over 200 radioactive prospects and mine sites have been located in New Mexico and include both non-productive prospects as well as properties with past mine production (Hatchell, 1981, pg. 44). Table IV-5 lists these and other properties by county, location, and geologic host rock.

Mining Costs

Mining costs depend on a variety of factors that may be peculiar to a single mine or mining situation. Such factors as ore grade, reserves, mine depth, size and distribution of the ore body, mineralogy of the ores and the amenability to milling, the competency of the host rock, dewatering requirements, utility costs, labor costs, royalty and taxation costs, and productivity per man hour all determine the profitability of a mining operation. Open-pit mining has traditionally been less expensive than underground mining, and hence lower grade material can be recovered.

Table IV-5. New Mexico uranium occurrences, non-productive prospects and abandoned mines as of July 1980 (New Mexico Mining and Minerals Division).

Uranium Mine or Prospect	County	Location	Host Rock
Junio (Cerro Colorado)	Bernalillo	T.9N, R.1W, SW/4 Sec. 1	Rhyolitic intrusion
Baby	Catron	T.10S, R.19W, Sec. 20	Rhyolite/fracture
Sec. 21 (Varnum)	Catron	T.3N, R.16W, NE/4 Sec. 21	Mesaverde (sandstone)
Quary	Catron	T.8S, R.17W, SW/4 Sec. 27	Basalt (?)
Midnight No. 2	Catron	T.2N, R.11W, W/2 Sec. 12	Point Lookout (?)
McPhaul Adit	Catron	T.2N, R.11W, SE/4 Sec. 14	Point Lookout Sandstone
Blue Star	Dona Ana	T.2N, R.3E, NW/4 Sec. 25	Fusselman Dolomite fault
ABC (Snooper claims)	Dona Ana	T.18N, R.2W, Secs. 33, 34	Santa Fe Group (sandstone)
		T.19N, R.2W, Secs. 4, 5	Santa Fe Group (sandstone)
Teepee (Rocky Arroyo)	Eddy	T.21S, R.24E, SE/4 Sec. 26	Yates Formation
Alhambra-Bluebelle No. 2	Grant	T.20S, R.15W, NE/4 Sec. 21	Diabase dike/Burro Granites
Floyd Collins	Grant	T.20S, R.15W, Secs. 21, 22	Diabase dike/Burro Granites
Merry Widow	Grant	T.20S, R.15W, S/2 Sec. 22	Burro Granite/diabase
Inez	Grant	T.20S, R.15W, S/2 Sec. 24	Burro Granite/diabase
Shamrock	Grant	T.20S, R.15W, SW/4 Sec. 23	Burro Granite/diabase dike
Calamity Mine	Grant	T.20S, R.15W, SE/4 Sec. 23	Burro Granite/vein (?)
Blue Jay	Grant	T.20S, R.15W, N/2 Sec. 26	Burro Granite/diabase dike
Eugenie	Grant	T.20S, R.15W, NE/4 Sec. 26	Burro Granite/ vein
Polita No. 2	Harding	T.17N. R.29E, NE/4 Sec. 6	Morrison Fm. (sandstone)
Mary No. 1 (Dysart No. 3)	McKinley	T.14N, R.10W, NW/4 Sec. 11	Morrison Fm. (Westwater)
Dysart No. 1 (Rio de Oro)	McKinley	T.14N, R.10W, SW/4 Sec. 11	Morrison Fm. (Westwater)
Dysart No. 2	McKinley	T.14N, R.10W, SE/4 Sec. 11	Morrison Fm. (Westwater)
United Western (J&M)	McKinley	T.14N, R.10W, NE/4 Sec. 36	Morrison Fm. (Westwater)
Sec. 26 (Ike No. 1)	McKinley	T.14N, R.9W, SW/4 Sec. 26	Morrison Fm. (Westwater)
Red Point Lode	McKinley	T.13N, R.10W, NW/4 Sec. 16	Todilto Limestone
Williams & Thompson (Sec. 18)	McKinley	T.13N, R.10W, SW/4 Sec. 18	Todilto Limestone
Sec. 24 (Glen & Edith)	McKinley	T.13N, R.11W, NE/4 Sec. 24	Todilto Limestone
Diamond 2 (Largo)	McKinley	T.15N, R.17W, N/2 Sec. 33	Dakota Sandstone
CD & S (Sec. 35)	McKinley	T.16N, R.17W, SE/4 Sec. 35	Morrison Fm. (Westwater)
Foutz No. 3 (Yellow Jacket)	McKinley	T.16N, R.16W, SE/4 Sec. 31	Morrison Fm. (Brush Base)

Table IV-5 (Continued)

Uranium Mine or Prospect	County	Location	Host Rock
Foutz No. 1 & No. 2	McKinley	T.15N, R.16W, NW/4 Sec. 4	Morrison Fm. (Westwater)
William & Reynolds	McKinley	T.15N, R.16W, SW/4 Sec. 4	Dakota Sandstone
Christenson (Rimrock No. 2)	McKinley	T.15N, R.16W, SW/4 Sec. 4	Dakota Sandstone
S.F. Christenson (Rimrock #1)	McKinley	T.15N, R.16W, SW/4 Sec. 3	Dakota Sandstone
Isabella	McKinley	T.13N, R.9W, SE/4 Sec. 6	Morrison Fm (Poison Canyon)
Spencer Shaft	McKinley	T.13N, R.9W, NW/4 Sec. 8	Morrison Fm (Poison Canyon)
Hogan	McKinley	T.13N, R.9W, SE/4 Sec. 14	Morrison Fm (Poison Canyon)
Gossett Incline (Beacon Hill #23)	McKinley	T.13N, R.9W, SE/4 Sec. 18	Morrison Fm (Poison Canyon)
Blue Peak (Garcia 1)	McKinley	T.13N, R.10W, NE/4 Sec. 24	Morrison Fm (Poison Canyon)
Mesa Top 7&8 (Malpais Raise)	McKinley	T.13N, R.9W, W/2 Sec. 20	Morrison Fm (Poison Canyon)
Dog Incline (Dog & Flea)	McKinley	T.13N, R.9W, NE/4 Sec. 20	Morrison Fm (Poison Canyon)
Marquez	McKinley	T.13N, R.9W, NE/4 Sec. 23	Morrison Fm (Poison Canyon)
Faith (Westvaco)	McKinley	T.13N, R.9W, W/2 Sec. 29	Todilto Limestone
Barbara J No. 3	McKinley	T.13N, R.9W, NE/4 Sec. 30	Todilto Limestone
Barbara J No. 1	McKinley	T.13N, R.9W, NE/4 Sec. 30	Todilto Limestone
Bailey and Fife (Rimrock ?)	McKinley	T.13N, R.9W, NE/4 Sec. 30	Todilto Limestone
Roundy Shaft	McKinley	T.13N, R.9W, SW/4 Sec. 30	Todilto Limestone
T-20 Shaft	McKinley	T.13N, R.9W, SE/4 Sec. 30	Todilto Limestone
Flat Top	McKinley	T.13N, R.9W, SE/4 Sec. 30	Todilto Limestone
SW/4-30 Strip Mine	McKinley	T.13N, R.9W, SW/4 Sec. 30	Todilto Limestone
Sec. 25 Strip Mine	McKinley	T.13N, R.10W, Sec. 25	Todilto Limestone
Sec. 25 Shaft	McKinley	T.13N, R.10W, N/2 Sec. 25	Todilto Limestone
NW/4-25, Decline & Open Pit	McKinley	T.13N, R.10W, NW/4 Sec. 25	Todilto Limestone
Hanosh	McKinley	T.13N, R.10W, NE/4 Sec. 26	Todilto Limestone
Sec. 23 & 26 Open Pit	McKinley	T.13N, R.10W, NE/4 Sec. 26	Todilto Limestone
NE/4-36 (Rimrock)	McKinley	T.13N, R.10W, NE/4 Sec. 36	Todilto Limestone
Sec. 31 Open Pit	McKinley	T.13N, R.9W, N/2 Sec. 31	Todilto Limestone
Moe No. 4	McKinley	T.13N, R.9W, Sec. 32	Todilto Limestone
Charlotte	McKinley	T.13N, R.9W, S/2 Sec. 33	Todilto Limestone
Hogback (Hogback 3-5)	McKinley	T.15N, R.18W, NE/4 Sec. 12	Dakota Sandstone
Becenti	McKinley	T.15N, R.17W, NW/4 Sec. 28	Dakota Sandstone
Kermac Sec. 10	McKinley	T.14N, R.10W, E/2 Sec. 10	Morrison Fm (Westwater)
Sec. 34 Mine	McKinley	T.14N, R.11W, NE/4 Sec. 34	Dakota Sandstone
Sec. 35 Strip Mine (Lost Mine)	McKinley	T.14N, R.11W, NW/4 Sec. 35	Dakota Sandstone
Febco (Small Stake)	McKinley	T.14N, R.10W, SW/4 Sec. 31	Dakota Sandstone
Silver Spur 1 (Silver Spur 5)	McKinley	T.14N, R.10W, E/2 Sec. 31	Dakota Sandstone
Pat	McKinley	T.13N, R.10W, NE/4 Sec. 4	Morrison Fm.
Dakota	McKinley	T.13N, R.10W, NE/4 Sec. 4	Morrison Fm (Westwater)
Junior	McKinley	T.13N, R.10W, NE/4 Sec. 4	Dakota Sandstone
Sec. 5-Westvaco No. 2	McKinley	T.13N, R.10W, W/2 Sec. 5	Dakota Sandstone
Sec. 1 Strip Mine	McKinley	T.13N, R.11W, Sec. 1	Dakota/Brushy Basin
Sec. 2 Strip Mine	McKinley	T.13N, R.11W, N/2 Sec. 2	Dakota Sandstone
Blackjack No. 1	McKinley	T.15N, R.13W, S/2 Sec. 12	Morrison (Poison Canyon)
Blackjack No. 2	McKinley	T.15N, R.13W, N/2 Sec. 18	Morrison (Poison Canyon)
Mac No. 2	McKinley	T.15N, R.13W, SE/4 Sec. 18	Morrison (Poison Canyon)
Mac No. 1	McKinley	T.15N, R.14W, SE/4 Sec. 12	Morrison (Poison Canyon,
Westwater	McKinley	T.15N, R.16W, SE/2 Sec. 2	Morrison Fm (Westwater)
Rialto (Chill Wills)	McKinley	T.13N, R.9W, NW/4 Sec. 24	Morrison Fm (Poison Canyon)
Alta	McKinley	T.14N, R.11W, SW/4 Sec. 5	Morrison Fm (Westwater)
Silver Bit 15 & 18 (Pentada)	McKinley	T.14N, R.12W, NE/4 Sec. 10	Dakota Sandstone
Francis	McKinley	T.14N, R.11W, NE/4 Sec. 8	Morrison Fm (Brushy Basin)
Evelyn	McKinley	T.14N, R.11W, NE/4 Sec. 9	Morrison Fm (Brushy Basin)
Billy-the-kid (Red Top 1)	McKinley	T.14N, R.11W, NE/4 Sec. 19	Todilto Limestone
Greer Warren & McCormack	McKinley	T.14N, R.11W, NE/4 Sec. 19	Todilto Limestone
Elkins	McKinley	T.14N, R.12W, NE/4 Sec. 24	Todilto Limestone
Maddox & Teaque	McKinley	T.14N, R.11W, NE/4 Sec. 19	Todilto Limestone
Glover	McKinley	T.14N, R.11W, NW/4 Sec. 20	Todilto Limestone
Red Top	McKinley	T.14N, R.11W, NW/4 Sec. 20	Todilto Limestone
Haven	McKinley	T.14N, R.11W, SW/4 Sec. 21	Todilto Limestone
Red Cap (T Group)	McKinley	T.14N, R.11W, NW/4 Sec. 28	Todilto Limestone
Yucca No. 2	McKinley	T.14N, R.11W, NW/4 Sec. 28	Todilto Limestone
Lulu Ann	Mora	T.22N, R.16E, unsurveyed	Sangre de Cristo (sandstone)
Good Luck	Quay	T.7N, R.31E, NE/4 Sec. 1	Chinle (middle sandstone)
		T.7N, R.32E, NW/4 Sec. 6	Chinle (middle sandstone)
Sec. 12	Quay	T.11N, R.33E, W/2 Sec. 12	Chinle (middle sandstone)
Little Rattler	Quay	T.11N, R.33E, Secs. 11, 12	Chinle (middle sandstone)
Lucky Strike	Rio Arriba	T.22N, R.2E, NE/4 Sec. 1	Chinle (Agua Zarca)
Hillfoot (Serrano)	Rio Arriba	T.22N, R.3E, NW/4 Sec. 8	Cutler Fm. (sandstone)
Red Head (Tinney No. 2)	Rio Arriba	T.22N, R.3E, NE/4 Sec. 8	Cutler Fm. (sandstone)
Tusas East Slope No. 5	Rio Arriba	T.28N, R.7E, NE/4 Sec. 24	Petaca Schist/fractures
J.O.L. (Royal)	Rio Arriba	T.28N, R.7E, NW/4 Sec. 24	Petaca Schist/fractures
Lucky Dog/Horny Toad	Rio Arriba	T.25N, R.5E, Secs. 29, 32	Dakota/Burro Canyon ?
La Paloma	Rio Arriba	T.26N, R.9E, N/2 Sec. 30	Pegmatite/Schist

Table IV-5 (Continued)

Uranium Mine or Prospect	County	Location	Host Rock
Pineapple	Rio Arriba	T.26N, R.9E, NE/4 Sec. 30	Pegmatite/schist
Whiteflow (Corral No. 3)	Rio Arriba	T.23N, R.1E, SW/4 Sec. 19	Cutler Fm (sandstone)
Box Canyon (Wasson)	Rio Arriba	T.23N, R.4E, NE/4 Sec. 28	Todilto Limestone
Collins (Warm Springs)	Sandoval	T.17N, R.1W, NW/4 Sec. 25	Morrison Fm (Brushy Basin)
Dory (Dorie)	Sandoval	T.12N, R.3W, NW/4 Sec. 8	Morrison Fm (Jackpile)
Betty	Sandoval	T.12N, R.3W, SW/4 Sec. 17	Morrison Fm (Jackpile) ?
Butler Brothers	Sandoval	T.19N, R.1W, NE/4 Sec. 23	Dakota Sandstone
Rambler No. 2	Sandoval	T.19N, R.1W, NW/4 Sec. 35	Mesaverde (Point Lookout)
Sla-Tex (Corral No. 3)	Sandoval	T.23N, R.1W, NE/4 Sec. 25	Cutler Fm (sandstone)
King Tutt No. 2	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
VCA Plot No. 7	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Franks Point (Plot 6)	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Lower Salt Rock	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Upper Salt Rock	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Williams Point (Plot No. 4)	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Salt Canyon	San Juan	T.29N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
VCA Plot No. 3	San Juan	T.29N, R.21W, Sec. 23	Morrison Fm (Salt Wash)
Tent	San Juan	T.29N, R.21W, Sec. 23	Morrison Fm (Salt Wash)
Begay Incline	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
Begay No. 2	San Juan	T.29N, R.21W, Sec. 23	Morrison Fm (Salt Wash)
Carrizo No. 1	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
King Tutt Point (VCA Plot #2)	San Juan	T.29N, R.21W, Sec. 23	Morrison Fm (Salt Wash)
Begay (Begay No. 1)	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
Red Wash Point (VCA Plot #1)	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
King Tutt No. 1 (MF6)	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
Junction	San Juan	T.29N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
Alongo	San Juan	T.29N, R.21W, Sec. 25	Morrison Fm (Salt Wash)
Canyon View (Alongo Claim)	San Juan	T.29N, R.21W, Sec. 25	Morrison Fm (Salt Wash)
Jimmy King No. 6	San Juan	T.30N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Barton and Begay	San Juan	T.30N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Rocky Flats No. 1	San Juan	T.30N, R.21W, Sec. 24	Morrison Fm (Salt Wash)
Canyon No. 1	San Juan	T.30N, R.20-21W, unsurveyed	Morrison Fm (Salt Wash)
John John No. 1	San Juan	T.30N, R.21W, Sec. 22	Morrison Fm (Salt Wash)
Jimmy King No. 2	San Juan	T.30N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Rocky Flats No. 2	San Juan	T.30N, R.21W, Sec. 26	Morrison Fm (Salt Wash)
Cottonwood Butte (VCA Plot 8)	San Juan	T.30N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Lone Star (VCA Plot No. 9)	San Juan	T.30N, R.21W, unsurveyed	Morrison Fm (Salt Wash)
Hogback Claim Pits	San Juan	T.30N, R.16W, Sec. 15	Point Lookout Sandstone
Dennet Nezz No. 1 & 2	San Juan	T.25N, R.20W, Sec. 5, unsur.	Morrison Fm (Recapture)
Dennet Nezz No. 3	San Juan	T.25N, R.20W, Sec. 5, unsur.	Morrison Fm (Recapture)
Horace Ben	San Juan	T.25N, R.20W, NW/4 Sec. 30	Morrison Fm (Recapture)
Sec. 8 Adit (unnamed)	San Juan	T.25N, R.20W, Sec. 8, unsur.	Morrison Fm (Recapture)
Kee and Tohe	San Juan	T.26N, R.20W, Sec. 31, unsur.	Morrison Fm (Recapture)
John Joe	San Juan	T.25N, R.21W, SE/4, Sec. 11	Morrison Fm (Salt Wash)
Castle Tsosie	San Juan	T.25N, R.21W, SE/4, Sec. 11	Morrison Fm (Recapture)
Joe Ben No. 2	San Juan	T.25N, R.20W, Sec. 6, unsur.	Morrison Fm (Salt Wash)
Joe Ben No. 1	San Juan	T.25N, R.20W, Sec. 6, unsur.	Morrison Fm (Salt Wash)
Joe Ben No. 3	San Juan	T.25N, R.20W, Sec. 8, unsur.	Morrison Fm (Salt Wash)
Carl Yazzie No. 1	San Juan	T.25N, R.20W, Sec. 17	Morrison FM (Salt Wash)
H.B. Roy No. 2	San Juan	T.25N, R.20W, Sec. 18, unsur.	Todilto Limestone
H.B. Roy No. 1	San Juan	T.26N, R.21W, unsur.	Morrison Fm (Recapture)
Reed Henderson	San Juan	T.25N, R.20W, Sec. 19, unsur.	Todilto Limestone
Boyd	San Juan	T.30N, R.15W, N/2 Sec. 3	Fruitland Fm (sandstone)
Sparks-Stone	San Miguel	T.16N, R.14E, Secs. 5, 6	Pegmatite
High Peak	San Miguel	T.17N, R.13E, N/2 Sec. 30	Pegmatite
Sabinoso (Asco)	San Miguel	T.17N, R.24E, SE/4 Sec. 8	Chinle (middle sandstone)
Windy No. 9	San Miguel	T.17N, R.23E, SE/4 Sec. 14	Chinle (middle sandstone)
Bish No. 2	San Miguel	T.17N, R.24E, NE/4 Sec. 31	Chinle (middle sandstone)
Verde (Hunt Oil Co. Sab)	San Miguel	T.27N, R.24E, W/2 Sec. 29	Chinle (middle sandstone)
Marion	Santa Fe	T.20N, R.10E, N/2 Sec. 7	Embudo Granite
Rodgers (Becky)	Santa Fe	T.20N, R.9E, Secs. 17, 20	Santa Fe Group (Tesuque)
San Jose	Santa Fe	T.20N, R.9E, Sec. 29	Santa Fe Group (Tesuque)
La Bajada	Santa Fe	T.15N, R.7E, NW/4 Sec. 9	Espinaso Volcanics
Red Rock Claim No. 1	Sierra	T.16S, R.4W, Secs. 28, 33	Granite/ fracture
Chise (Trujillo Lease)	Sierra	T.12S, R.7W, Sec. 18	Abo Fm (conglomerate)
Mitchell Price	Sierra	T.13S, R.5W, Sec. 12	Magdalena Limestone
Sierra	Sierra	T.17S, R.4W, N/2 Sec. 4	Granite/fracture
Glory/Empire	Sierra	T.10S, R.8W, Secs. 13, 14	Abo Fm (siltstone)
Pitchblende Strike (Terry)	Sierra	T.10S, R.6W, Sec. 26	Kelly Ls (jasperoid breccia)
Red Tiger (Bobby Johnson)	Sierra	T.13S, R.7W, Secs. 1, 2	Abo Fm (siltstone)
Paran	Sierra	T.17S, R.4W, Sec. 27	Madera Ls. (fault)
Lucky Don (Bonanza)	Socorro	T.2S, R.2E, NE/4 Sec. 35	San Andres Ls/fracture

In-situ solution mining may ultimately prove to be successful as a low cost extraction method in the San Juan Basin of New Mexico. Table IV-6 shows estimated uranium recovery cost ranges for New Mexico.

The New Mexico Mining Association calculates that during 1979 the average cost required to produce a pound of uranium concentrate at the mill was $29.83. By October 1980, this production cost had escalated to $35.50 per pound, an increase of 19 percent over a period of less than one year (New Mexico Mining Association, oral testimony, November 1980).

Table IV-5 (Continued)

Uranium Mine or Prospect	County	Location	Host Rock
Little Davie	Socorro	T.2S, R.2E, NE/4 Sec. 35	San Andres Ls/ fault
Hook Ranch (Jara Losa)	Socorro	T.1N, R.6W, SW/4 Sec. 13	Baca Fm (sandstone)
Jackpot No. 1	Socorro	T.2S, R.1W, W/2 Sec. 5	Madera Ls.
Jeter (Charlie No. 2)	Socorro	T.3N, R.2W, NE/4 Sec. 35	Popotosa Fm.
Union No. 1	Socorro	T.1S, R.3E, SW/4 Sec. 31	Abo Fm (sandstone)
Big Chief No. 4	Socorro	T.4S, R.3W, SW/4 Sec. 3	Andesite (Tertiary)
Black Copper Canyon	Taos	T.28N, R.15E, Sec. 26, uns.	Granite gneiss
Copper Girl	Torrance	T.4N, R.5E, NW/4 Sec. 28	Abo Fm (conglomerate)
Double Jerry (Vallejo)	Valencia	T.12N, R.9W, NW/4 Sec. 3	Todilto Limestone
Christmas Day	Valencia	T.12N, R.9W, NE/4 Sec. 4	Todilto Limestone
Red Bluff Claims	Valencia	T.12N, R.9W, N/2 Sec. 4	Todilto Limestone
Black Hawk/Bunney	Valencia	T.12N, R.9W, SE/4 Sec. 4	Todilto Limestone
Red Bluff 7-10/Gay Eagle	Valencia	T.12N, R.9W, S/2 Sec. 4	Todilto Limestone
Last Chance	Valencia	T.12N, R.9W, NE/4 Sec. 8	Todilto Limestone
Section Nine	Valencia	T.12N, R.9W, Sec. 9	Todilto Limestone
Taffy (Bonanza)	Valencia	T.12N, R.9W, SW/4 Sec. 11	Morrison Fm (Poison Canyon)
La Jara	Valencia	T.12N, R.9W, SE/4 Sec. 15	Todilto Limestone
Zia	Valencia	T.12N, R.9W, SW/4 Sec. 15	Todilto Limestone
Sandy (So. Laguna Mines)	Valencia	T.9N, R.5W, Secs, 22, 27	Todilto/Entrada
F-33 (Anaconda)	Valencia	T.12N, R.9W, Secs. 33, 34	Todilto Limestone
Tom 13	Valencia	T.11N, R.9W, SW/4 Sec. 4	Todilto Limestone
Lone Pine	Valencia	T.11N, R.9W, NE/4 Sec. 8	Todilto Limestone
Cedar (Yucca, Falcon)	Valencia	T.11N, R.9W, SE/4 Sec. 20	Todilto Limestone
Chavez (Canoncito)	Valencia	T.10N, R.3W, SE/4 Sec. 22	Morrison Fm (Recapture)
Woodrow	Valencia	T.10N, R.5W, Sec. 1	Morrison Fm/breccia pipe
		T.11N, R.5W, Sec. 36	Morrison Fm/breccia pipe
San Mateo	Valencia	T.13N, R.8W, NE/4 Sec. 30	Morrison Fm (Poison Canyon)
Crackpot	Valencia	T.8N, R.5W, NW/4 Sec. 8	Todilto Limestone
Paisano Prospect	Valencia	T.8N, R.6W, NW/4 Sec. 16	Todilto Limestone
UDC 1-4	Valencia	T.12N, R.9W, SE/4 Sec. 4	Todilto Limestone

*Abandoned mines do not include temporarily idle mines. Refer to Table IV-3 for a list of currently idle mines as of 12/01/80.

Table IV-6. Estimated current uranium recovery cost ranges in New Mexico. Cost estimates are calculated by applying the U.S. Bureau of Labor Statistics Industrial Commodities Index as a cost escalation factor using 1977 dollars. These ranges are only estimates and are not actual costs which may vary greatly for individual operators. Specific data for New Mexico are available only for underground mining costs. The calculations exclude miscellaneous and other royalty costs. (New Mexico Bureau of Geology used modified 1977 U.S. Department of Energy cost data and New Mexico Taxation and Revenue Department tax data).

Acquisition and exploration costs \$/lb U_3O_8	Ore Haulage costs \$/ton of ore	Severance taxes \$/lb U_3O_8	Excise taxes \$/lb U_3O_8	Total average taxes \$/lb U_3O_8
1.74-9.78	0.67-3.62	1.09-3.24	0.15-0.38	1.24-3.62

	\$/ton of ore		
	Capital	Operating	Total
Underground mining costs	5.36-25.46	37.52-60.30	42.88-85.76
Open-pit mining costs	9.38-18.76	6.70-18.76	21.44-28.14
Conventional milling costs	1.34- 5.36	6.70-14.74	8.04-20.10

Editor's Note- As this report goes to press, production from the Jackpile-Paguate open pit mine has ceased; Production from underground operations however are continuing. The Bokum Marquez mine is still uncompleted at this time. The Conoco-Wyoming Mineral Corporation mine project at Crownpoint has been halted due to the depressed uranium market. Gulf Minerals is proceeding with underground development and production at Mount Taylor. Phillips Uranium has completed the sinking phase of the two Nose Rock shafts and the installation of permanent pump stations is now in progress.

CHAPTER V

URANIUM MILLING and RECOVERY OPERATIONS

This chapter will deal with many of the aspects of uranium concentrate production in New Mexico, except for environmental concerns which will be covered in Chapter X. The chapter will discuss both uranium ore milling facilities and uranium recovery facilities (resin bed ion exchange) for uranium contained in liquids. Next the chapter will discuss resource needs for milling, including employment, land, water, and energy. This section will be followed by a presentation of recent legislation which affects the industry. Taxation and revenue to the state from the industry will then be discussed.

CONVENTIONAL MILLING OF ORES

Techniques

Because uranium ore contains only small quantities of uranium, it is necessary to concentrate the uranium at mills located close to the mines in order to avoid large shipping expenses. The ore is hauled from the mines in trucks; or in the case of the transport of ore from the Jackpile-Paquate complex, in trains. The ore may be stockpiled at the mill until needed or it may be unloaded into the first processing stage of the mill. (New Mexico Health and Environment Department).

All but one of the mills active or planned for New Mexico use an acid leach process. (New Mexico Health and Environment Department). While there are some differences in each mill the general procedure is to: 1) grind the ore to separate the material so that the leachate can penetrate more easily; 2) leach the ground material with H_2SO_4 using an oxidant (usually $NaClO_3$ although Anaconda uses MnO_2) to render the uranium more soluble; 3) separate the sands and slimes (barren) from the uranium containing solution - usually some type of cyclone and counter current decantation and filtering process; 4) remove the uranium from the solution by means of solvent extraction; 5) remove the uranium from the organic solvent extraction solution; 6) precipitate the uranium; and 7) wash, dry, and package the uranium concentrate-usually 85% or more U_3O_8 (New Mexico Health and Environment Department).

The one mill which does not use a sulfuric acid leach uses an alkaline leach process. The ore in the alkaline leach process is ground (but much finer) and leached (including pressure leaching). The uranium is removed from the leachate, purified using several process steps, and dried. (New Mexico Health and Environment Department; Merritt, 1971).

In both types of circuits, the waste which consists of the spent chemicals and most of the solids entering the mill, is sent to tailings piles.

Figures V-1 and V-2 indicate typical flow diagrams for uranium mill circuits. (U.S. Department of Energy, Grand Junction Office, no date).

Trends in Milling

Ores which contain a great deal of limestone must be processed using an alkaline leach because of excessive acid use if an acid leach is used. While some New Mexico ore has Todilto Limestone as its host rock, the production in the Todilto is decreasing and this trend is expected to continue. There does not appear to be a need for new mills to use an alkaline leach process. (U.S. Department of Energy, Grand Junction Office).

Ores known as refractory ores have been produced from New Mexico mines for many years. These ores were either stockpiled or run through the mill in small amounts with other less refractory ores.

In future years the milling of refractory ores may increase if New Mexico's reserves are to be recovered. Many of the new areas coming into production appear to contain at least some of these types of ores. The design of new mills and the modification of old mills, thus, may have to include processes to increase recovery from refractory ores.

An investigation of the Nose Rock ore by D.W. Rhett in 1979 indicated that the ores that are difficult to leach displayed no consistent differences in coffinite composition or host-rock mineralogy compared to the easily-leached ore. What was found was that it was the carbonaceous organic matrix which presented the problem with the uranium being contained: 1) in isolated, very small (submicron) crystals located throughout the organic, or 2) as an ultra fine-grained, cryptocrystalline or amorphous component in the organic matter. The data obtained by Rhett would indicate that dissolution of this uranium is diffusion controlled (Rhett, 1979).

In another study, personnel at the Bureau of Mines studied leaching of ore contained in the "Jackpile" sandstone near Laguna, New Mexico. Sample

Figure V-1. Flowsheet - Acid Leach Solvent Extraction (U.S. Department of Energy, Grand Junction Office).

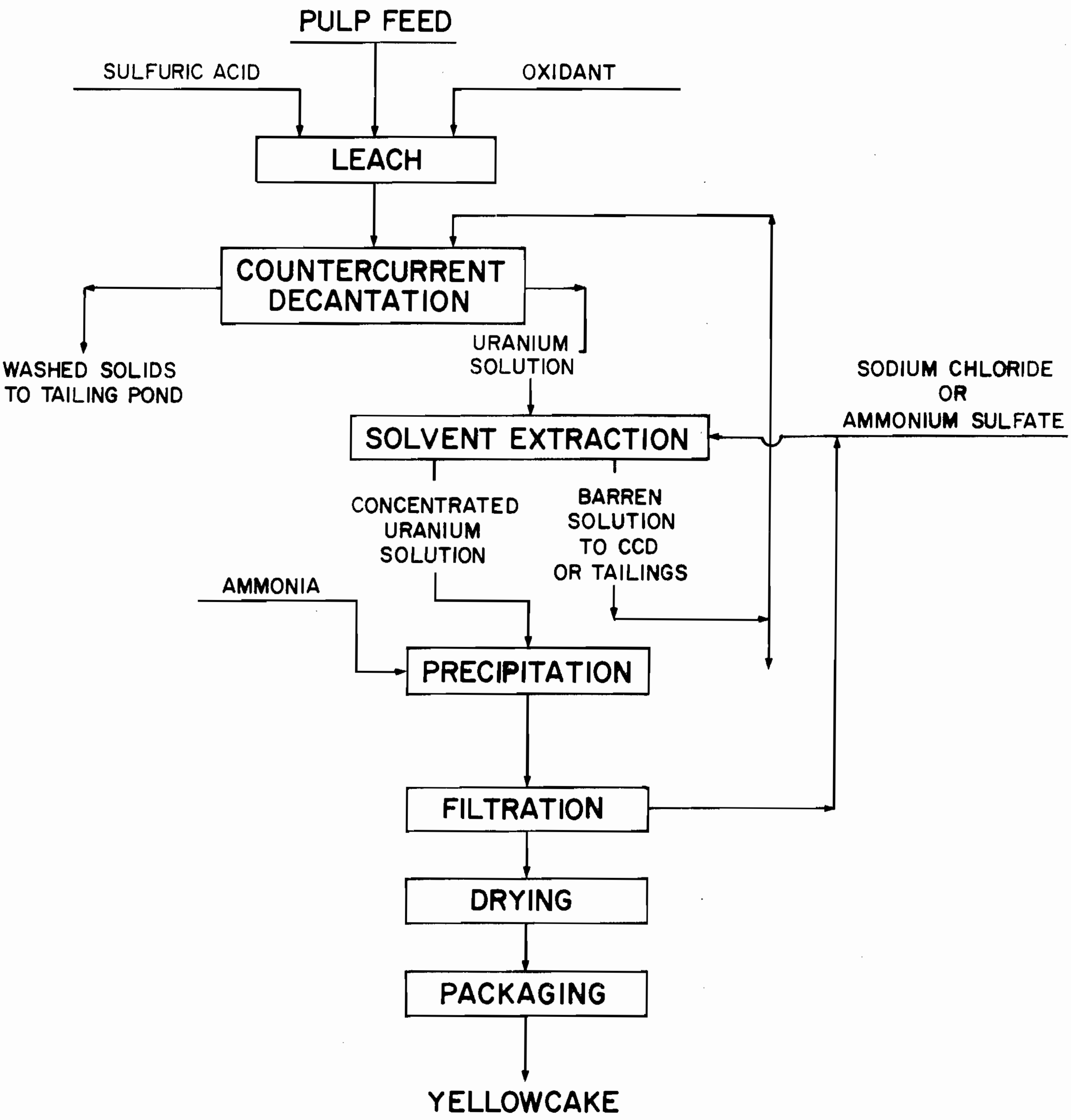
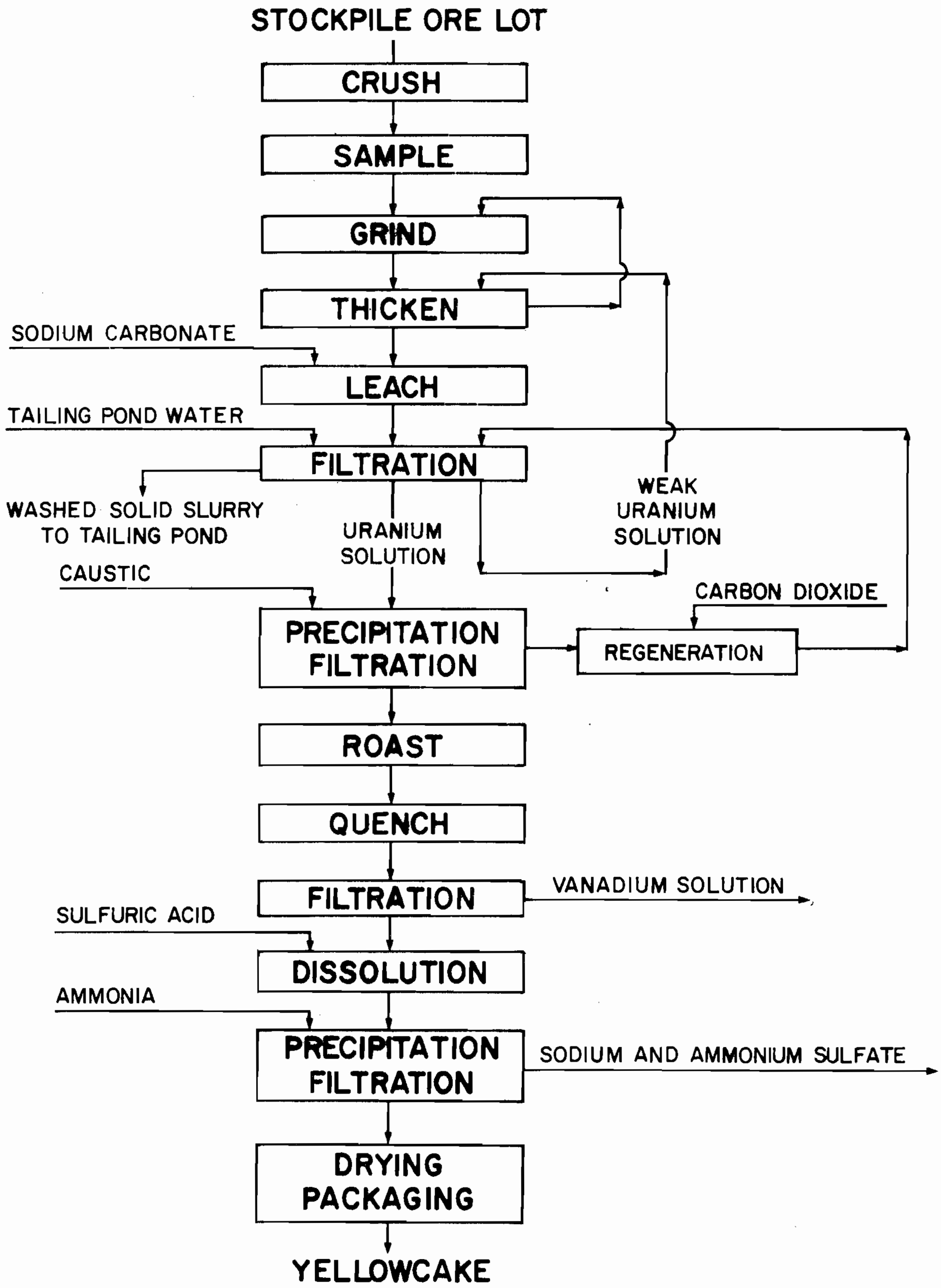


Figure V-2. Flowsheet - Alkaline Leach, Caustic Precipitation (U.S. Department of Energy, Grand Junction Office).



1 contained 0.18 percent U_3O_8 and 0.26 percent organic carbon, sample 2 contained 0.26 percent U_3O_8 and 0.71 percent of organic carbon, and sample 3 contained 1.08 percent U_3O_8 and 10.9 percent organic carbon. Thus, the richer U_3O_8 samples contained the most carbon. These samples were subjected to the various treatments shown in Table V-I.

This data would indicate that uranium recovery from the ore with the highest carbon content was very poor using conventional leaching techniques at ambient temperatures and that only by roasting was a high recovery (greater than 95 percent) obtained (Nichols et al., 1979).

Roasting operations require environmental controls and increase costs, therefore, autoclave leaching was also tried. On sample 3, 93 percent U_3O_8 extraction was achieved using 35 mesh, 20 percent solids, 3-hour leach, 200°C, 260 psig (pounds per square inch guage) including steam and 50 psi (pounds per square inch) oxygen partial pressure and 100 lb/ton H_2SO_4 (Nichols et al., 1979).

Since it would be less expensive to treat, using special techniques, only that part of the ore that required this special treatment for maximum recovery, the Bureau also tried flotation to concentrate the carbonaceous material. A pilot-scale flotation test was conducted at the New Mexico Bluewater mill on the acid-leach tailings stream. The flotation concentrate sample responded well to a roast-leach treatment, which extracted 93 percent of the uranium. Autoclave treatment of the flotation concentrate removed 90 percent of the uranium under the optimum conditions, with a 95 percent extraction resulting from a two step leach, that maximized oxidation conditions (Nichols et al., 1979).

In another study to improve extraction of uranium from refractory ores, D. A. Milligan (1977) investigated optimum roasting conditions. For ore coming from the Jackpile-Paguate complex, organic carbon content had been found to equal 1.9 times the U_3O_8 content. Increased uranium losses in leach residue were also noted at the higher organic carbon content. In laboratory studies, Milligan found that roasting at specified times and temperatures increased extraction from high organic Jackpile-Paguate ores (Milligan, 1977). Too high temperatures during roasting may, however, decrease recovery. Specific salts may be added so that temperature control is less critical.

The U.S. Bureau of Mines has also studied a flotation - nitric acid leach procedure for increasing recovery.

Table V-1. Treatment of "Jackpile" Sandstone Samples (Nichols et al., 1979).

Sample 1 - low carbon

Process	Temp° C	H_2SO_4 lb/ton	$NaClO_3$ lb/ton	extraction % U_3O_8
no roast	23	50	0	82
no roast	23	100	0	87
no roast	23	50	5	92
no roast	23	100	5	94
no roast	50	50	5	91
roast	50	50	0	97
roast	50	50	5	97

Sample 2 - intermediate carbon

Process	Temp° C	H_2SO_4 lb/ton	$NaClO_3$ lb/ton	extraction % U_3O_8
no roast	23	50	0	64
no roast	23	100	0	72
no roast	23	50	5	89
no roast	23	100	5	89
no roast	50	50	5	89
roast	50	50	0	99
roast	50	50	5	99

Sample 3 - high carbon

Process	Temp° C	H_2SO_4 lb/ton	$NaClO_3$ lb/ton	extraction % U_3O_8
no roast	23	50	0	43
no roast	23	100	0	51
no roast	23	50	5	79
no roast	23	100	5	79
no roast	50	50	5	87
roast	50	50	0	98
roast	50	50	5	99

While each ore must be studied individually for maximum U_3O_8 extraction, it would appear that special treatment may be necessary for some New Mexico ores, particularly those ores containing significant amounts of organic carbon. (New Mexico Health and Environment Department; Carnaham and Lei, 1979; Nichols et al., 1979; Merritt, 1971; Milligan, 1977; Rhett, 1979).

Inactive New Mexico Mills and Tailings Piles

Table V-2 provides data on the inactive tailings piles located in New Mexico. The Bluewater and Milan piles are associated with presently active facilities (Dames and Moore, 1977; New Mexico Health and Environment Department).

The Shiprock mill was located on an approximately 230-acre-site on the south side of the San Juan River on the outskirts of Shiprock. The mill was constructed and operated from 1954-1963 by Kerr-McGee Oil Industries, Inc. and from 1963-1968 by Vanadium Corp. of America and its successor, Foote Mineral Company. When Foote Mineral's lease expired in 1973, full control of the site reverted to the Navajo Nation, from whom the land had originally been leased. During its operation, the mill reportedly processed 1.5 million tons of ore by using an acid-leach process with an average grade of 0.25 percent U_3O_8 (including ore concentrate from Monument Valley) to produce 3,711 tons of U_3O_8 in concentrate. Vanadium was also produced in 1955, and 1960-1968. The ore was trucked an average distance of 100 miles from northeastern Arizona, northwestern New Mexico, and the Uravan Mineral Belt. Several of the original buildings are still at the site and are being used (Sears et al., 1975; Douglas et al., 1975; Ford, Bacon, and Davis, March 1977; Hans et al., 1978; Haywood et al., 1979; New Mexico Radiation Protection Bureau).

There are two tailings areas at the Shiprock mill. Gamma surveys, measurements of ambient radon levels and radon diffusion from the piles, and analysis of soil samples have all been undertaken. (Sears et al., 1975; Douglas et al., 1975; Ford, Bacon, and Davis, March 1977; Hans et al., 1978; Haywood et al., 1979). The tailings have been partially stabilized; however, the continued emission of radionuclides from these piles and the location of the site in Shiprock has resulted in concern by the Navajos as to the possible adverse effects due to the piles (See Chapter X). The Shiprock site will be one of the four sites which will receive the first remedial action (perhaps as early as late 1980), under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA).

Table V-2. Inactive Tailings Piles in New Mexico (New Mexico Health and Environment Department, Radiation Protection Bureau).

Company	Location	Area Acres	Height (Ft)	Tons Tailings	Status
Foote Mineral	Shiprock	26 46	14-40 15 average	1,700,000	Operated 1954-1968, partly stabilized
Phillips	Ambrosia Lake	91	3 to 33	2,684,000	Operated 1958-1963, not stabilized
Homestake - New Mexico Partners	Milan	48	NA	1,218,000	Operated 1958-1962, not stabilized
Anaconda	Bluewater	24	NA	584,184	Operated 1953-1956, partly stabilized
Anaconda	Bluewater	51	NA	180,849	Partly stabilized

The old Phillips mill (Ambrosia Lake) was located about 22 miles north of Grants in Section 28, T. 14N., R 9W. The mill was built in 1957 and was operated at a throughput of about 1,750 tons per day until early 1963 by Phillips Petroleum Company (Sears et al., 1975; Ford, Bacon and Davis, December 1977; Haywood et al., 1980). United Nuclear Company purchased the mill at that time but only operated it until April 1963. UNC (United Nuclear Corporation) is presently using the main building for offices and has an ion exchange facility located at the site. The company also uses the area for parking equipment, shops, etc. UNC has indicated that they would like to dismantle part of the mill and sell various pieces of the equipment. In order to do this, the company must have the planned procedure approved by the State of New Mexico's Health and Environment Department and will have to follow this plan to insure safe levels of radioactivity on equipment leaving the site. Using an alkaline leach, the mill processed 3 million tons of ore (average grade 0.23 percent U_3O_8) from nearby mines. All the wastes were sent to the nearby tailings pile. Phillips removed 333,700 tons of sands from the tailings for the purpose of backfill in nearby mines. In addition, UNC removed 59,000 tons of sands, which were also used as mine backfill. (Ford, Bacon and Davis, December 1977).

Studies have been made of radon flux from the pile, radium concentrations in soils, and gamma levels around and on the pile. Despite the fact that the toxic substances in this pile have been shown to be moving into the surrounding environment, remedial action at this site will probably be delayed until remedial action on tailings in less remote areas is completed. Reclamation of the pile could begin as early as 1982. Remedial action for abandoned tailings piles is under the control of DOE (U.S. Department of Energy) and is being conducted in cooperation with New Mexico. The DOE is planning to conduct experiments for possible reclamation schemes on this tailings pile. The remoteness of the site makes it attractive for these experiments. Under the Mill Tailings Radiation Control Act of 1978, New Mexico will have to pay 10 percent of the cost of remedial action on the Phillips pile. Gerald Stewart of EID (New Mexico Environmental Improvement Division) has estimated that costs could run between 3-30 million.

The Homestake-New Mexico Partners mill began operation as an alkaline-leach (carbonate) mill in early 1958 and operated with a throughput of about 750 tons per day until April 1962. In 1961, the property had been acquired by the operators of the adjacent Homestake-Sapin Partners mill. Most of the mill's buildings are still standing at the present time and UN-HP (United Nuclear-Homestake Partners) uses some of the equipment as part of their present mill. The tailings pile from the Homestake-New Mexico Partners operation is located near the present active UN-HP tailings area (Merritt, 1971; Perkins, 1979).

The Anaconda inactive tailings piles were generated during early operation of this mill (Dames and Moore, 1977).

Neither the Homestake-New Mexico Partners mill nor the inactive Anaconda tailings piles have been accepted as tailings piles eligible for the Federal government to pay 90 percent of the rehabilitation costs.

Licensed New Mexico Mills

Excluding the Phillip's mill there are six licensed uranium mill facilities in New Mexico; all but one of these is actively processing ore. Data on these is given in Table V-3. Data on the active tailings piles associated with the active mills is given in Table V-4. Each mill circuit will not be discussed in detail since this information is available in the references listed at the end of this publication (Merritt, 1971; Mining Engineering, p.28-30, 34-36, 1974; Kerr-McGee Corporation, no date; Sohio, Reserve Oil and Minerals, no date; United Nuclear-Homestake Partners, no date).

The Anaconda Bluewater mill, Section 24, T. 12N., R 11W., was the first mill constructed in New Mexico that is still in active operation. The Bluewater mill was first built with an alkaline circuit, which was used from 1953-1956. As ore from the "Jackpile" sandstone mined at Anaconda's Jackpile-Paguate complex began to come into the mill, a more efficient acid circuit was constructed. Constant modifications to the mill have been made through the years (Merritt, 1971; Dames and Moore, 1977; New Mexico Health and Environment Department).

Several years ago, an autogenous grinding facility was installed, and the resin-in-pulp section was replaced by a solvent-extraction section. A new leach section has just been completed. This section has equipment to remove acid vapors and radon from the area, will be more reliable, and should have reduced maintenance requirements. By February 1981, a new precipitation, drying, and packaging section should be completed. This section will have a design capacity of 25,000 lbs per day of U_3O_8 output. Thus, by mid-1981, Anaconda will have replaced all of the sections of the mill and will have in effect, a "new mill" (New Mexico Health and Environment Department, Radiation Protection Bureau).

This mill is licensed for less than the capacity for which it was designed. In addition to the 25,000 lbs per day "backend" capacity, the "front-end" of the mill can handle, while in operation, up to 9000 tons per day of ore.

The ore from the Jackpile-Paguate complex at Laguna is brought to the mill by unit train. This is the only ore presently milled by Anaconda. During the first 5 months of 1979, Anaconda ran an average of 5,280 tons of ore per day with an average production of 10,000 lbs per day U_3O_8. Beginning in mid-1979 Anaconda increased throughput somewhat. Present ore grade is running approximately 0.09 percent. Unless some ore is toll milled the grade is expected to continue to be less than 0.1 percent for the next few years as the remaining stockpiles and low grade ore from the Jackpile-Paguate complex is milled and production continues from the underground facilities in the complex. Final milling of the ore from the Jackpile-Paguate will probably occur several years from now. (Anaconda Company, personal communication, June 1980).

Table V-3. Licensed Uranium Mill Facilities in New Mexico as of July 1, 1980 (New Mexico Health and Environment Department, Radiation Protection Bureau).

Company	Location	Present Licensed Capacity tons/day	Start Up	Type	By-Products
Sohio Oil Reserve Oil & Minerals	Seboyeta	1,660	1976	acid	none
Kerr-McGee Nuclear Corp.	Ambrosia Lake	7,000	1958	acid	Mo
Anaconda	Bluewater	6,000	1953	originally alkaline now acid	none
United Nuclear	Church Rock	4,000	1977	acid	none
United Nuclear - Homestake Partners	Milan	3,500	1958	alkaline	V
Bokum	Marquez	2,200	?	acid	none

Table V-4. New Mexico Mill Tailings Piles and Decant Ponds (New Mexico Health and Environment Department).

OPERATOR	LOCATION	EFFECTIVE DATE	TONS TAILINGS (millions)	TAILINGS TOTAL SURFACE (acres)	TAILINGS LIQUID SURFACE (acres)	MAXIMUM HEIGHT (feet)	NUMBER OF DECANT PONDS	TOTAL SURFACE DECANT PONDS ACRES
Sohio	Seboyeta	4/30/80	1.758	130	75	50	0	0
Anaconda	Bluewater	4/1/80	18.850	266	30	60	4	221
Kerr-McGee	Ambrosia Lake	1/1/80	27.100	250	40	100	21	350
UN-HP	Milan	4/1/80	18.535	150[1]	50	85	0	0
UNC[2]	Church Rock	4/23/80	2.400	200	27.5	NA	2	13.4[3]

1 at base of pile

2 conditions are changing due to interim operations and may change further when a permanent tailings area is constructe

3 changes have been required as a result of a tailings spill July 16, 1979

As production from the Jackpile-Paguate complex declines and then stops, the future source of ore for the mill remains unknown.

A recent development at Anaconda in waste management has been the construction of decant ponds for excess tailings liquor. These ponds are extensive (Table V-4) and have all been lined with suitable liners. Engineers at Anaconda are looking at the possibility of taking the partially evaporated liquor from the decant ponds (approximately 1000 gallons per minute); running this liquor through a uranium extraction circuit (probably some type of solvent extraction); adjusting pH to precipitate solids, perhaps using reverse osmosis; and then recycling the liquid back into the mill circuit. This process would minimize the cost and need for new decant ponds; reduce the chance of: 1) an accident releasing decant, or 2) seepage from the ponds; and reduce the pumping costs for the well water which now supplies the mill.

Engineers are also looking at processes to increase recovery of uranium from the ore. For example, the Bureau of Mines study was mentioned in an earlier section.

Including the Jackpile-Paguate mine complex, approximately 1200 persons were employed at the Anaconda mine-mill facilities as of June 1980 (Anaconda Company, personal communication, June 1980).

Another acid-circuit mill which has been in operation for a number of years is Kerr-McGee's mill in Section 31 T. 14N., R. 9W. at Ambrosia Lake. The mill was constructed in 1958 at a cost of $18 million dollars to serve the mines which Kerr-McGee had under development (Kerr-McGee Corporation, no date). At the present time the Kerr-McGee Ambrosia Lake mill processes approximately 6,500 tons per day except for a 3-week maintenance period in the summer. Ore comes from Kerr-McGee's mines. In addition, production from Mariano Lake, the Ruby Mines, Johnny M., Cobb's mines, and some from Sandstone, Anne Lee, and Section 27 is toll milled. Mill grade has historically run approximately 0.2 percent U_3O_8. The yellowcake is shipped to Kerr-McGee's UF_6 refinery and also to Allied Chemical by truck in 55-gallon barrels. Including two surface mines in Wyoming, during 1979, Kerr-McGee Nuclear produced 5.1 million lbs of U_3O_8 and 5.3 million lbs of U_3O_8 during 1978. Kerr-McGee has indicated that 1980 production is expected to exceed the 1978 output (Mining Engineering, 1974; Kerr-McGee, no date; Kerr-McGee, 1979).

Detailed data on the Kerr-McGee mill circuit can be obtained from mill license and discharge permit applications to the New Mexico Health and Environment Department, Merritt (1971), Mining Engineering (1974) and Kerr-

McGee. Kerr-McGee has recently added additional units to the washing circuit. More ores of the type requiring (for maximum recovery) longer grinding times, and increased temperatures and retention times in the leach circuit are being processed by the mill. Sands, separated from the waste material discharged by the mill, are sent to Sections 35 and 36 and to the Johnny M. Mine for use in backfill. Kerr-McGee is continuing to build new decant ponds for the tailing liquor. It was found that for lining the ponds CPE works better than PVC and the new ponds are being lined with this material. Study of chemical reactions, rate of evaporation of decant liquor, and treatment and reuse of decant liquor is being undertaken. It appears that the rate of evaporation of the decant liquor remains the same regardless of how long the liquor has been in the pond. Many of the soluble salts are precipitating out.

Kerr-McGee has installed a scrubber on the yellowcake dryer off-gases and a baghouse on the packaging area off-gases. These collectors should considerably reduce yellowcake emissions to the ambient atmosphere.

Kerr-McGee engineers are looking at ways to improve the mill circuit. For example, the use of hydrogen peroxide in the precipitation section is being studied.

Water for the mill comes from the ion exchange facility located at the mill site, which receives mine water from the Section 17, 19, 22, 24, 30, 33, and 30W mines.

Total employment at the mill is approximately 205.

A relatively new acid-circuit mill which began operation in 1976 is Sohio-Reserve Oil and Mineral's mill located near Seboyeta. The mill was constructed to process ore mined from the nearby JJ No.1 Mine. Ore from the other two projected Sohio-Reserve mines to be developed in the area will also be milled. In addition, the mill has tolled ore from other nearby mines, the St. Anthony and Jackpile-Paguate complexes (Woodward-Clyde, 1980). The average grade processed so far by the mill has been 0.124 percent U_3O_8 with ore grades ranging from 0.06-0.21 percent. New units in the washing circuit were recently installed to improve uranium recovery. Present recovery is approximately 85-88 percent on a 0.1 percent U_3O_8 ore (Sohio, personal communication, June 1980). Besides the small amount of water (about 100 gpm) coming from the JJ No.1, the mill obtains its process water from wells completed into the "Jackpile" and Westwater. Total water needs are 500-550 gpm. (gallons per minute) The mine-mill presently employs about 380 persons.

This employment is projected to increase to 545 in 1982 and 1983 and decline to 480 in 1985 (Sohio, personal communication, June 1980).

UNC's mill at Church Rock was built as an acid-leach mill to process the ore from UNC's large Northeast Church Rock mine. In addition, ore from UNC's Old Church Rock mine and Kerr-McGee's large Church Rock No.1 mine is also milled (New Mexico Health and Environment Department; United Nuclear Corporation, personal communication, June 1980).

The mill began operation in 1977 and throughput was gradually increased to 4,000 tons per day (New Mexico Radiation Protection Bureau). On July 16, 1979 a breach occurred in the earthen tailings dam. The company estimates that 100 million gallons of process liquid, which contained dissolved radioactive and heavy metal contaminants and 1,100 tons of solids were discharged into the nearby Rio Puerco (Puerco of the West). Radioactive contamination of the banks of the stream have been followed to the Arizona border. A massive monitoring and clean-up program was initiated with extensive monitoring still continuing. The more seriously contaminated areas have been scraped and the material placed on the UNC controlled tailings pile. A comprehensive report should be available from the State of New Mexico Radiation Protection Bureau of the Environmental Improvement Division within the next year detailing the very expensive and time-consuming monitoring and clean-up activities. The spill has so far cost the State of New Mexico between $350,000 - $500,000 for staff time, travel, monitoring, and tests.

After the dam break, the mill was shut down until October 27, 1979. At that time, limited milling began. The tailings were placed a distance up from the breached area, and decant was placed in two decant ponds. The mill was ordered closed by EID (New Mexico Environmental Improvement Division) for 5 days in November. During May-July 1980, the mill was working on a 10-day-on/4-day-off cycle and intends to run this type of cycle for the rest of the year. Throughput during days of operation is about 2,500 tons per day. This limited operation is necessary to prevent tailings liquor from rising above the level set by EID in the decant ponds. At the present time UNC and the State of New Mexico are studying seepage rates and liquid movement from the decant ponds and seepage recovery techniques. The starter dam breach has been repaired (Nuclear Fuel, August 1976, May 1980; Albuquerque Journal, July 1980). Tailings are being cycloned to provide sand backfill at UNC's Church Rock Mine.

The State has asked UNC to work on alternative waste management schemes involving new tailings disposal sites. In January 1980, UNC submitted a list of alternative sites, and further study of these sites is being undertaken.

Makeup water for the mill comes from the UNC Northeast Church Rock mine. During 1980, approximately 600-800 gpm of decant water from the decant ponds was being treated with lime and ammonia to raise pH to slightly above 4 and the precipitates were being removed in a CCD circuit. The treated water was then being used in the milling circuit. This procedure was reported to be working well (United Nuclear Corporation, personal communication, June 1980).

In February 1980, UNC Resources Inc. announced the sale of 3.16 million lbs U_3O_8 to Korea Electric Co. for delivery in 1980-1982 (Wall Street Journal, February 1980).

A cut-back of 20 percent in production was announced by UNC in April 1980 to 2.8 million lbs of production from 3.5 million lbs in the last fiscal year (Nuclear Fuel, March 1980).

The only alkaline (carbonate) mill now in active operation is the UN-HP (United Nuclear-Homestake Partners) mill near Milan. This mill is the former Homestake-Sapin Partners mill (Merritt, 1971; Mining Engine ering, 1974). Throughput at this mill has been running about 3,000 tons per day. It is the only mill which can handle the limestone ores of the Hope, Haystack, and Piedra Triste mines. In addition, ore from UN-HP mines in the Ambrosia Lake area is also processed at this mill. Some ore from UNC's Ambrosia Lake mines has also been run. No major changes have recently been made in the circuit. Roasting has not been done prior to leaching for a number of years. While it is possible to use the dryer, this has not been used for about a year. Two-stage leaching is still in use and the filters have been rebuilt. The company's engineering section is presently studying the possibility of using peroxide in the precipitation section. The ion exchange facility installation at the mill will be discussed later in this chapter.

Mining of limestone host-rock ores is expected to decline rapidly in the next few years. In addition active UN-HP mines in the Ambrosia Lake area probably have a lifetime at the most of about 10 years. The mill thus may soon have some excess capacity.

The most recently licensed New Mexico mill is the Bokum mill at Marquez in Section 32 and 33, T. 13N., R. 4W. This mill was designed as an acid-circuit mill. Construction of the mill is almost complete; however, progress has been delayed in recent months. Additional funding needed to finish the mine-mill complex is estimated at be \$20-40 million (Nuclear Fuel, May 1980, July 1980; Bokum Resources, personal communication, July 1980). The tailings disposal area is in a basin several hundred feet below the mill itself (which is located on a mesa). Subsurface disposal of tailings with decant of liquor from tailing drainage to evaporation ponds is planned.

It was thought that ore from the Bokum mine at Marquez would provide part of the mill feed and that toll contracts would provide the rest. While the Bokum mine now under development has production targeted at 1,500-2,000 tons per day when in full production from three shafts, extensive delays in the main shaft sinking operation have prevented the completion of this shaft and no toll contracts have been signed. There are no nearby mines now in production which do not already have milling facilities; however, there are two mines on standby status.

The ore from the Bokum Marquez properties is projected to be fairly easy to mill in a two stage leaching circuit. It is not believed that molybdenum or organics will pose problems. The mill was designed for an approximate 96 percent recovery on a average 0.12 percent U_3O_8 ore.
A maximum of 400 persons were employed during mill construction. Permanent employment for the operating mill operates has been projected at 45.

Mills Announced For Construction

There are presently three publicly announced construction projects of new mills. Data on these projects is given in Table V-5.

Table V-5. Mills For Which Construction Has Been Publically Announced (New Mexico Health and Environment Department, Environmental Improvement Division).

Company	Location	Requested License Capacity (Tons per day)	Status
Gulf	San Mateo	4,200	License application approved
Phillips	Nose Rock	2750 (may double later)	License application submitted
WMC-Conoco	Prewitt(*)	1,000 - 1,500	Beginning background studies & mill circuit design

* other sites being investigated

Gulf has proposed construction of a mill near San Mateo in Section 1, T. 13N., R. 8W. estimated to cost $80 million. This mill would process the ore from the nearby Gulf Mount Taylor mine. A mill with a final initial input capacity of 4,200 tons per day and output capacity of 25,000 lbs per day U_3O_8 is proposed. For the initial three years of operation the mill throughput would be 2,000 tons per day. Average ore grade is expected to be 0.3 percent U_3O_8 (New Mexico Health and Environment Department).

The ore is somewhat refractory and the molybdenum ratio is expected to be approximately 15:1. Thus, molybdenum will be recovered and the present design of the mill circuit indicates fairly intensive ore treatment; however, no roasting or pressure leach circuit is presently included in the mill design. While initial design of the mill is complete, final details are awaiting completion. Jacob Engineering has been asked by Gulf to do no further mill design work at this time (New Mexico Radiation Protection Bureau).

The proposed tailings site is in Sections 10,11,14 and 15, T. 14N., R. 8W. The present plan is to dig 50-ft-deep trenches, 75-ft wide at the bottom, 125-ft wide at top, and one-half mile long. The tailings would be transported by a pipeline carrying 20-40 percent solids by weight. The liquid draining in the trench would be decanted to a slimes settling pond and then sent to a 200-acre evaporation pond. The operating equipment would place material from digging the new trench onto the clay cover of the old trench, which would be filled within 5-ft of the top with tailings. Gulf has also indicated that about 50 percent of the tailings (sands) may go back to the mine for backfill. This would require a review and license amendment by EID (New Mexico Radiation Protection Bureau).

Another proposed mill project (Section 12, T. 19N., R. 12W.) to serve the Nose Rock mine under development is the Phillips Nose Rock mill. The license application is for a mill capacity of 2,750 tons per day. Ore grade has been indicated as averaging 0.14 percent U_3O_8. For this grade, mill efficiency is estimated at 96-98 percent. Retention time has been initially designed for 20 hours at a temperature of 80°C. Since fines are more refractory, they may receive additional treatment. Molybdenum will be recovered as a by-product (New Mexico Health and Environment Department). By November 1980, the mill design was about 85 percent complete and the final design work had been placed on "hold" (Phillips Uranium Corporation, personal communication, November 1980).

The original tailings disposal plan was to separate sands and liquid/slimes, placing the sands in cells to finally cover 250 acres, and placing the liquid/slimes in a 220-acre pond with a capacity for holding a 20-year production of slimes (New Mexico Health and Environment Department).

At the present time the Radiation Protection Bureau of EID has requested that Phillips look at several sites and evaluate these for the best site and to study alternative tailings disposal methods. Phillips has control of approximately 60,000 acres in the Nose Rock area and has indicated that a multiple mine system with a combined lifetime of at least 20 years will be developed to provide ore feed to the mill (New Mexico Natural Resources Department, 1979).

Conoco Inc., in conjunction with Wyoming Mineral Corp. (Westinghouse), has announced a proposed mill to be built for processing the WMC-Conoco Mineral Crownpoint mine production. The announced design throughput is 1,000 - 1,500 tons per day. The mill will be processing an average grade ore of 0.15 percent U_3O_8 over a projected lifetime of 17 years (Wall Street Journal, August 1979; Nuclear Fuel, September 1979). While the design of the mill is preliminary, an acid-leach circuit is planned. As far as is known, the ore will be low in molybdenum, vanadium, and organics and will pose no special milling problems. A definite site has not yet been purchased, though a site near Prewitt appears to be the most favorable. Conoco is trying to buy water rights in the area.

The mill will employ approximately 75 people. Water demand, once the mill is in operation will be about 70 - 100 gpm to process 1,000 tons per day, since it is anticipated that process water will be treated and recycled.

Ore production from the Crownpoint mine is scheduled to begin in late 1982; due to the time lag for mill construction (site acquisition, pre-operational monitoring, discharge permit and mill license approval, construction, etc.), it is possible that ore will either have to be stored at the mine for some time or the mine's production will have to be tolled.

Wyoming Mineral's financing of the project allows them to receive all yellowcake production until the initial investment is recovered; then, Conoco and Wyoming Mineral will share production costs and uranium production on a 50-50 basis (Wall Street Journal, August 1979; Nuclear Fuel, September 1979).

Possible Mills

The Grand Junction Office of DOE (United States Department of Energy) has a confidential data base of ore reserves and locations in New Mexico. Using this data, John Klemenic (1979) of the Grand Junction staff has indicated that there are ore reserves available in the state to support additional mills at Crownpoint and the Rio Puerco of the East. In addition to these two mills, Klemenic indicates that "probable" potential resources, which if they indeed develop into reserves, could supply ore for additional mills at Ambrosia Lake, East Chaco Canyon, Mt. Taylor, and Shiprock (Klemenic, 1979).

U_3O_8 RECOVERY FROM RESIN BED ION EXCHANGE TECHNIQUE

For uranium recovery from liquids, a suitable resin bed can be used to remove the uranium from the liquid. By chemical addition the uranium can then be removed from the resin. The uranium containing liquid originates in several ways and these wll be discussed in the following sections. Data on IX facilities is given in Table V-6.

Mine Water Recirculation and Mine Water Inflow

Extensive use is being made of mine water recirculation to recover uranium from low grade ores left behind during conventional ore recovery in underground mines. Holes (usually approximately 2 inches inside diameter) are drilled from the surface of the ground down to the top of the ore body or collapsed zone. These holes are usually spaced about 50 ft apart. Special spray nozzles are installed in the bottom of the hole and recirculated mine water is carried down the hole and sprayed onto the low grade material in approximately a 25-ft-diameter circle. Air is also carried down the hole. Natural air circulation in the mine and the air from the surface holes oxidize the previously insuluble uranium so that the uranium can be dissolved in the slightly alkaline mine water as uranyltricarbonate. When the uranium content of the mine water decreases, spraying may be discontinued for a time to allow for further oxidation of uranium to occur. In the mines of one operator, rainbirds which are placed on the floor of the mined out areas are also used to spray the rubble and waste piles (Perkins, 1979; New Mexico, Water Pollution Control Bureau).

The pregnant solution flowing from the low-grade material is collected in sumps in the mine and is pumped to the surface into settling-holding ponds. From there the water can either be recirculated for further building up of

Table V-6. Present and Proposed Uranium Ion Exchange Facilities, November 1980 (New Mexico Health and Environment Department).

Company	Location	Source	Type	GPM	Disposition of Pregnant Liquor
UNC	Church Rock	NE Church Rock mine	mine water flow	1,200	Enters surge tank before solvent extraction at UNC Church Rock mill
UNC	Ambrosia Lake	Ann Lee Sandstone Sec 27 mines	most is water recirculation some inflow	500–600	Pregnant solution sent to UN-HP mill by truck. Joins pregnant liquor at mill IX.
UN-HP	Ambrosia Lake	Sec 32	mine water inflow (plans for recirculation)	1,700–1,800 IX 1,100–1,200 recirculated back to mines	"
		Sec 23	inflow & recirculation		
		Sec 25	inflow & recirculation		
		Sec 15 Mines	"		
Gulf	Smith Lake	Mariano Lake mine	mine water inflow	200 – 230	Pregnant solution trucked Kerr-McGee. Enters mill at clarifier.
Kerr-McGee	Ambrosia Lake (located at mill)	Sec 22 Sec 33 Sec 17 Sec 30 Sec 24 Sec 30W Sec 19	Minewater inflow & recirculation " " " inflow (plans for recirculation) inflow	2,500	Enters K-M mill at clarifier.
Kerr-McGee	Ambrosia Lake	Sec 35 mine	Minewater inflow	1,500 – 1,600	Loaded beads to strip at K-M mill IX.
Gulf+	Mt. Taylor	Mt. Taylor mine	Minewater inflow	4,000	–
UNC	Church Rock	Old Church Rock mine	Minewater inflow at av. 225 gpm water/ storage in ponds until run through IX	600 – 800 (only 4-5 days per wk	To sump after clarifier at UNC mill.
Mobil+++++	Crownpoint (South Trend)	In-situ leach	recirculation chemical addition	N/A	Uranium precipitated at site.
Mobil++	Crownpoint (North Trend)	In-situ leach	"	"	–
Kerr-McGee++	Church Rock	Church Rock mine	water inflow	3,800	–
UN-HP	Milan at mill site	tailings decant water	decant	1,700	Uranium precipitated at the facility.
Exxon++	Bibo (San Antonio Valley)	In-situ	recirculation chemical addition	–	U_3O_8 precipitated at site.
UNC++++	Ambrosia Lake	Heap leach	recirculation	1 gpm	Liquor to UNC Ambrosia Lake IX.
Mobil+++	Monument Site (East Crownpoint)	In-situ leach	recirculation chemical addition		Uranium precipitated at site.
Phillips++	North Nose Rock	In-situ leach	aquifer restoration test chemical addition		N/A
UNC++++	Section 13 Old Church Rock Area	"	push-pull test for in-situ feasibility		To UNC mill.

+ constructed but not presently in operation
++ proposed
+++ proposed – wells in place
++++ finished test, not now in operation
+++++ pilot plant to begin aquifer restoration soon. Full scale plant proposed

uranium, or it can be piped to the central IX (ion exchange) facility. After removal of the uranium in the ion exchange, the barren water can either be discharged after suitable treatment, recirculated, used as drill water, etc. in the mine, or sent to a mill for use as mill process water (New Mexico Health and Environment Department; Perkins, 1979).

Natural water inflow into the mines also contains uranium in solution and is treated similarly to the water recirculated (if it contains sufficient uranium to warrant recovery).

These ion exchange facilities use various chemicals for stripping the loaded resin. A description of the UN-HP mine IX and treatment of the pregnant liquor published several years ago by R. C. Merritt (1979) is included below to indicate how this particular operation works. Company personnel indicate that this is still the procedure used.

> "Water pumped out of the United Nuclear-Homestake Partners mines in the Ambrosia Lake area is treated to recover dissolved uranium by resin ion exchange in fixed bed columns located near the mine sites. Pregnant eluate solution from the operation is transported by truck 16 miles to the mill for final treatment.
>
> Four 16-foot diameter by 8-foot high extraction columns each containing 480 cubic feet of quaternary amine-type resin are used in a series-parallel arrangement. Approximately 1,700 gallons per minute of mine water is passed upflow through the columns for an average cycle time of 8 days. Effluent water contains less than 1.0 ppm U_3O_8 which represents an extraction of about 96 percent. Portions of this effluent water are pumped back to augment the underground leaching operations. Average resin loading is 4 pounds of U_3O_8 per cubic foot.
>
> Elution is accomplished with four bed volumes of recycle eluate followed by four bed volumes of eluant containing 90 grams of NaCl and 4 grams of $NaHCO_3$ per liter. Utilizing the split elution technique, the eluant, after passing through the columns, is saved as recycle eluate for the next elution cycle. Recycle eluate, after a second passage through the columns, is recovered as pregnant eluate and contains between 12 and 16 grams of U_3O_8 per liter.
>
> Precipitation of a uranium product from the eluate is accomplished independently of the main mill circuit by heating to 190°F, acidifying to a pH of 3.0 with HCl to decompose the carbonate, and then adding NaOH to pH 7.0 to precipitate the yellow cake. This slurry is filtered on presses and the cake then transported in drums to the main plant where it is fed into the yellow cake thickener following the caustic precipitation stage. Approximately 13,000 pounds of U_3O_8 are recovered."

Kerr-McGee recently formed a leaching section in order that more attention could be given to mine-water recirculation. The 1979 annual report states, "A program to increase recovery of uranium by underground leaching resulted in several leach areas coming on stream in New Mexico in 1979, with production reaching about 59,000 pounds of U_3O_8, up from 33,000 pounds in 1978" (Kerr-McGee Corporation, 1979).

As is shown in Table V-6, Kerr-McGee has announced plans to install an ion exchange facility at their Church Rock mine. The uranium content of the mine water entering the plant is expected to be equal to or greater than 2 mg/l and the discharge is expected to contain approximately 0.1 mg/l. Approximately seven elutions per month will be required. The pregnant solution from the elution operation is expected to contain 10-20 g/l of uranium, and about once a week a shipment of this solution will be sent in a 5000 gallon capacity tanker to Kerr-McGee's mill. Uranium production from this mine water/IX is expected to be about 33,4000 pounds of uranium per year (New Mexico Health and Environment Department).

Tailings Decant Water

In addition to the mine-water recirculation method, uranium can also be recovered from the uranium contained in tailings decant liquor (Table V-6). UN-HP has used this technique for several years on the decant from their tailings at their Milan mill. The facility is located in the old Homestake-New Mexico Partners mill. As indicated in the discussion from Merritt in the previous section, the pregnant solution has the uranium precipitated from it at the IX facility. UN-HP has recently installed a 16-ft, five stage NIMCIX ion exchange column. In this type of column, the beads move on trays and are systematically moved in the loading column over to the stripping column. This column is more efficient and should lower operating costs (New Mexico Health and Environment Department).

As indicated previously, Anaconda is also considering removal of uranium from tailings decant; however, they may use an organic rather than a bead type ion exchange.

Heap Leach

Use of heap leach is another method of recovering uranium from low-grade materials. A suitable pad is usually placed on the ground, and drain tiles, or similar liquid channels, are installed. The material to be leached is piled on top and retention basins may be contoured at the top. The liquid is placed on the top of the pile, and as it moves downwards, it solubilizes the oxidized uranium. The pregnant solution draining from the pile can then be piped to a nearby ion exchange plant for U_3O_8 recovery. The barren solution from the IX can then be again placed at the top of the heap pile.

Presently UNC has constructed a heap leach facility in Section 27, T. 14N., R. 9W. The pile is about 10-16 ft high on top of a plastic pad with a gravel drain placed on top of the pad. The material runs about 0.02 percent U_3O_8. A tap off of one of the mine water pipes allows for mine water to be discharged onto the top of the pile. After the drainage water (approximately 1 gpm) is caught in a sump, it is pumped to the UNC IX at the Old Phillips Mill for recovery of uranium from the liquid. After using mine water, chemical addition to the leachate or use of bacteria colonies may be investigated.

There are several, abandoned heap-leach projects in the Ambrosia Lake area. It is reported that Homestake operated a test pile in Section 25 in about 1966. It was found that the liquid moved very slowly through the material, and the project was discontinued. It is believed that only mine water was used; however, it is possible that chemical addition was used for a short period of time.

Kerr-McGee also tried heap leach of low-grade material at a location at the north edge of the mill tailings pile. Mine water was used as the leachate. This project probably took place sometime in 1970-1971, but it is reported that excessive channeling occurred and the project ceased operation. The piles are still present sticking out of a present decant pond.

It has been reported that UNC had a heap leach in Section 27 (United Nuclear Corp., personal communication, June 1980).

The author has also spotted an abandoned heap leach just in front of the old San Mateo mine in Section 30, T. 13N. R. 8W. This operation was probably constructed by UNC or El Paso Natural Gas (who operated the San Mateo Mine before UNC).

Grace Nuclear also had a small heap leach in Section 13, T. 1N., R. 6W. The ore of the Baca host rock was piled about 6 ft high on top of a concrete pad approximately 20 ft-by-10 ft. Ammonium bicarbonate was added to increase pH of the leach water. It is not known how long this facility operated or if any uranium was ever recovered. The concrete pad and ore pile on the pad are still at the site (New Mexico Health and Environment Department; New Mexico Water Pollution Control Bureau).

IN-SITU PROJECTS

Presently (November, 1980) there is one active pilot in-situ project and several in-situ projects are planned.

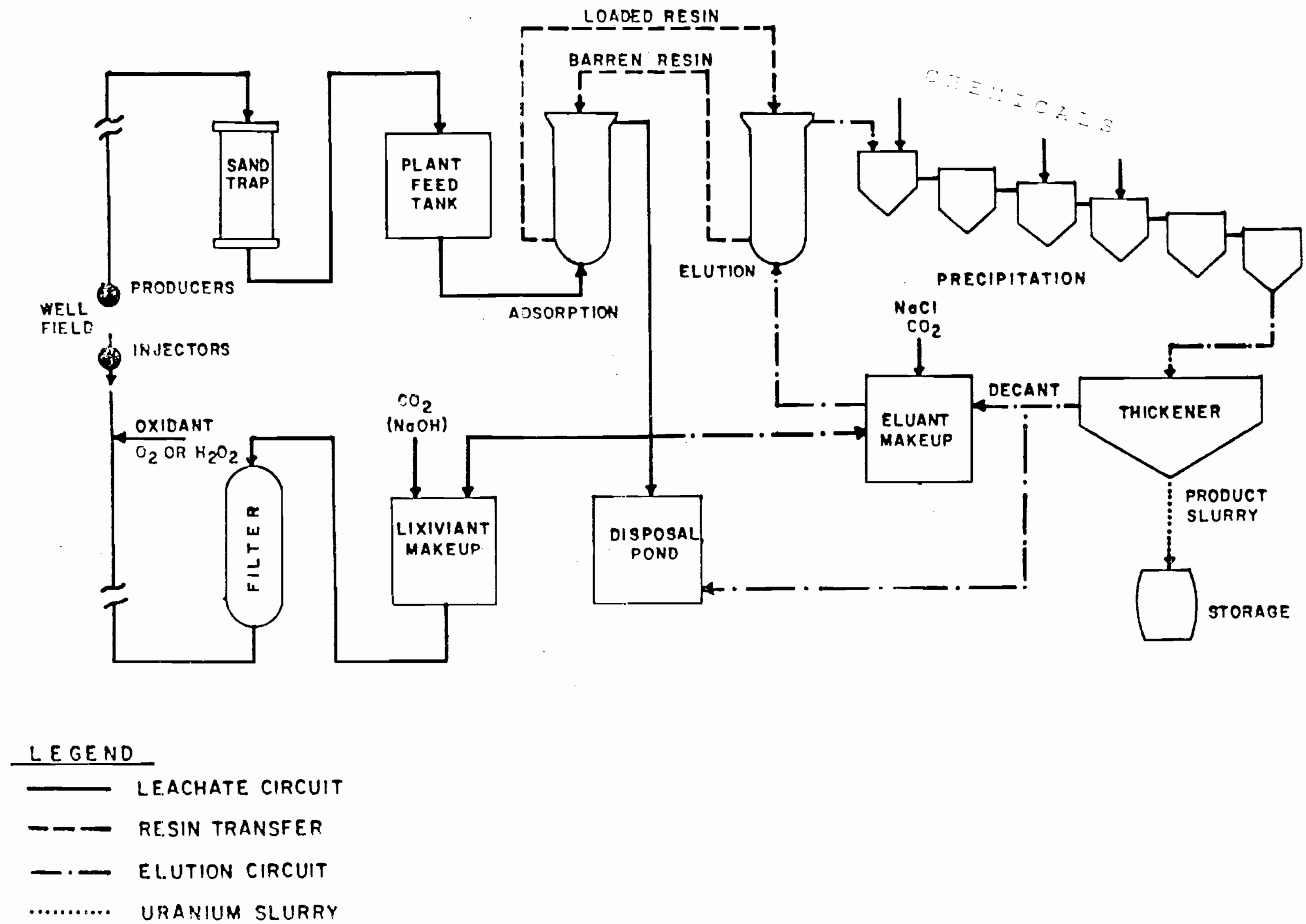
Mobil In-situ Projects, Crownpoint Area

As of November 1980, Mobil Oil (with a 25 percent interest in production by Tennessee Valley Authority) has a pilot plant in-situ leach project in operation in Section 9, T. 17N., R. 13W. near Crownpoint. In addition, Mobil plans another pilot project (Monument), in Section 28, T. 17N., R. 12W., for which the test wells have been installed. One other pilot project near Crownpoint may also be undertaken. In addition to the pilot projects, a full scale project is planned for an area near the present pilot plant.

In the present pilot plant, nine injection, four production, and 12 monitoring wells have been drilled to approximately 2,000 ft with the production and injection wells being completed in the Westwater host rock. The ore-bearing sandstone in this region is about 30 ft thick. The wells have a 5½ inch OD (outside diameter) casing of plastic-coated steel as deep as the Westwater. In the Westwater, the wells are cased with fiberglass. A slightly alkaline solution was pumped into the injection wells. This solution reacted with the uranium in the Westwater, causing it to go into solution; then the pregnant solution was brought to the surface in the production wells. The uranium was removed by ion exchange from the solution and the barren solution after addition of an alkaline chemical and an oxidant was reinjected. The uranium was removed from the ion exchange resin beds through addition of sodium chloride and the uranium enriched solution from the stripping side of the ion exchange was transfered to a surge tank from where it was pumped through the precipitation and slurry concentration circuits. The uranium was precipitated by means of pH adjustment. A diagram of these procedures is shown in figure V-3. Bleed went to a plastic-lined pond.

During the summer of 1980, two different types of ion exchange systems were tested. One was a countercurrent fluidized bed system with resin transfer from the adsorption column to the elution column via a resin storage tank occurring at regular intervals. The other system, a Higgins loop, had a continuous resin bed moving in a pneumatic pulsed loop in which adsorption and elution occurred in the various sections of the loop. In addition to these two systems, various resins and removal of various elements being

Figure V-3. Process Flowsheet for an In-situ Leach Pilot Plant (New Mexico Health and Environment Department



carried in the pregnant solution underwent study. Experiments were also conducted in the precipitation circuit, with testing of various means of pH adjustment, thickening, etc.

The pilot plant production/extraction efficiency is currently being evaluated by Mobil. A concentrated uranium slurry has been produced by the pilot plant, but no shipments have been made.

The addition of chemicals to the injection well fluids began in November 1979. By October 1980, enough data had been obtained that restoration of the well field could begin.

During well field restoration, the use of chemical leaching additives to the injection well fluids has been discontinued. In November 1980, the production fluid will be run through ion exchange. This will continue until low uranium levels in this fluid are obtained. The production fluid will then be run through a reverse osmosis unit and recirculated in a new injection well until the fluids in the well field return to a water quality similar to pre-leaching water quality. Well-field restoration is expected to take about 8 months. The site occupies about 5 acres. After the project is finished the equipment will be removed and the area reseeded. It has been estimated that approximately 5 curies per year of radon-222 may be released by the Crownpoint pilot project. Approximately 25 persons are employed in the Crownpoint leach project (New Mexico Health and Environment Department; Mobil Oil, 1977-1978).

If the pilot projects are successful, uranium in ore-pods that are too isolated and too small for shaft mining techniques could be recovered. The following statement was made in the August 7, 1978 issue of Nuclear Fuel, "In-situ leaching has the potential of increasing the recoverable uranium reserves at Crownpoint by a factor of five." Mobil has recently proposed construction of a full scale in-situ facility to be located near the present pilot plant. In addition, the Monument site east of Crownpoint is a planned test scheduled for late 1980, and the company has indicated interest in an additional test facility to be located north of Crownpoint within its North Trend ore body.

UNC - Teton Push-Pull Project

In April 1980, the New Mexico EID gave permission for UNC Teton Exploration Drilling, Inc. to conduct a limited push-pull test in Section 13, T. 16N., R. 17W. Teton notified EID that the test was carried out in June, 1980.

The surface owner of the land is the Navajo Tribal Trust (Water Pollution Control Bureau, personal communication, June 1980).

Teton proposed to withdraw approximately 4,500 gallons of water from a well completed into the uranium bearing zones of the Morrison Formation (approximately 1,300 ft deep at the location of the well). The water was to be stored in a 5,000-gallon-capacity pool.

According to the plan, the water had approximately 2 gram per liter sodium carbonate/bicarbonate and 0.75 gram per liter hydrogen peroxide added to it, with the water to be reinjected into the Morrison. After 5 days, the well was pumped at the rate of 5 gpm. The fluid was then run through an ion exhange facility and then into the swimming pool. The liquid in the swimming pool was pumped into trucks and carried to the nearby UNC mill for use in the mill. A total of approximately 13,500 gallons of fluid was pumped from the well. Uranium recovered in the ion exchange was expected to be less than a total of 5 lbs. A diesel 30 Kilowatt generator furnished the electrical needs for the project. If this push-pull project gave favorable results, further in-situ leaching may be attempted in a field test at the site (Ford, Bacon and Davis, December 1977; Water Pollution Control Bureau, personal communication, June 1980).

Proposed Exxon In-situ Leach Project

Exxon is planning an in-situ leaching project in Section 21, T. 12N., R. 4W., at their San Antonio Valley orebody between Bibo and Marquez. Exxon owns mineral rights on 60,000 acres in this area. The target ore body is in the Westwater Canyon Member of the Morrison Formation approximately 925 ft below the surface. The mineralized sands are 55-70 ft thick and contain approximately 0.09 percent U_3O_8.

Exxon plans 20 production, 12 injection, and 10 monitor wells with a five-spot configuration. Four production wells will ring an injection well. There will be a 70 ft spacing on the diagonal between an injection and production well. All wells will have fiberglass casing. The entire project will occupy approximately 2.75 acres.

An alkaline fluid will be injected in order to solubilize the uranium. Up to 20 grams per liter each of sodium carbonate and sodium bicarbonate, plus up to 1.5 grams per liter of hydrogen peroxide will be added to the injection fluid of approximately 140 gpm. The pregnant solution from the production wells will be taken to an ion exchange facility where the uranium will be transferred from the solution to resin beads. Sodium chloride and sodium carbonate will be used to remove the uranium from the beads. This concentrated U_3O_8 solution will then have the uranium precipitated to produce a 15 percent solids slurry through pH charge using either an acid and base or acid and hydrogen peroxide. The slurry will then be sent by slurry truck to a drying and packaging facility. The barren solution coming from the ion exchange will have suitable chemical additions and will then be reinjected. Approximately 2-7 gpm will probably need to be bled from the system to prevent buildup of unwanted contaminants, such as radium, arsenic, selenium, and molybdenum. All bleed and any other waste water (such as rain runoff, system wash water, etc.) will be piped to the nearby Sohio mill and used as process water there. An on-site standby lined lagoon for waste water will also be constructed.

The target U_3O_8 slurry production is approximately 9000 lbs of U_3O_8 per month. Construction of the facility is planned for late 1980 (though by November 1980, no construction had begun) and early 1981. By mid-1981, it is hoped that leaching can begin. The leach phase of the project should last through 1984. From the end of leaching until the field is restored should take an additional 2 years.

To restore the leached area, approximately 75-100 gpm of fluids will be withdrawn. The water will be run through the ion exchange as long as there are sufficient U_3O_8 concentrations in the fluids. All fluids will be sent to the Sohio mill. It is estimated that a total of approximately 300-500 acre-ft of water will have to be withdrawn through the leached sands before water quality returns to its original parameters. Power will be obtained from the existing nearby PNM line. It is expected that approximately 23 people will be employed at the project. Using data obtained from their Wyoming in-situ projects, Exxon has estimated that approximately 14.5 uCi/sec of radon will be produced as radon comes out of solution from the production fluids (Exxon, 1980).

Phillips

Phillips Uranium Corporation submitted a proposal in June 1980 to the New Mexico EID for an in-situ leach project in Section 32 T. 19N., R. 12W. This initial test is being termed a "restoration field test." The company proposes to use two wells (which would later become part of a 5-spot pattern) into the Westwater Canyon Member, some 3,700-3,400 ft below the surface. One well would be used for injection and one for recovery. It appears, after testing recirculation of Westwater fluids, that H_2SO_4 may be added to the injection water to increase mobilization of the uranium. After the leaching step, aquifer restoration will be studied. Disposal of water taken from the aquifer during the operation may be by deep well injection (New Mexico Health and Environment Department; Water Pollution Control Bureau, personal communication, June 1980).

Grace Nuclear

In addition to the present and proposed in-situ projects, Grace Nuclear operated two uranium recovery in-situ projects. The first project was in Section 23, T. 16N., R. 17W. There were six injection wells and two production wells completed into the Westwater, approximately 500 ft below the surface. The production wells delivered at approximately 40 gpm. The uranium was recovered in an IX. Approximately 18 gpm of the water from the IX was discharged to a nearby arroyo and 22 gpm were returned to the Westwater. A small amount of ammonium bicarbonate was added to increase the pH of the injected water. When the beads in the IX were loaded, they were stripped. The pregnant solution was transported to the Kerr-McGee mill. It is reported in the license application that approximately one truck a month went to the mill (New Mexico Health and Environment Department).

Grace Nuclear had a similar project in Section 13, T. 12N., R. 4W. The target host rock was again the Westwater. This project is no longer in operation; however, chemicals at the site and open wells have been reported by the staff of EID.

RESOURCE NEEDS

Employment

Employment in milling for the years 1975-1979 is given in Table V-7. This table also indicates ore weighed and sampled and gives the ore-employee ratio. Table V-8 breaks out employment by group in 1979. To construct a mill of approximately 4,000-5,000 tons per day capacity, it has been estimated that 810 man-years are needed (U.S. Energy Research and Development Adm., 1976 - 1977; U.S. Department of Energy, 1978, 1979a, 1980a).

Water

A New Mexico acid mill presently requires approximately 1½ tons of water for every ton of ore processed (though some require slightly more and some slightly less). If water is treated and reused, water needs will of course be reduced (Sears et al., 1975).

An alkaline mill characteristically requires less water than an acid mill. Some construction water is necessary during the building of a tailings dam and for raising the retention dam. Gulf has estimated, for example, that approximately 800 acre-ft of water per year will be necessary at their facility for raising the retention dam (New Mexico Health and Environment Department).

Table V-7. Employment in Milling (U.S. Energy Research and Development Admin., 1976 - 1977; U.S. Department of Energy, 1978, 1979a, 1980a).

Year	Employment	Tons of ore weighed & sampled	Tons of ore per employee
1975	852	2,985,000	3,504
1976	1,046	3,401,000	3,251
1977	1,021	4,209,000	4,122
1978	1,127	6,262,000	5,556
1979	1,160	6,880,000	5,931

Table V-8. Employment Categories in Milling for 1979 (U.S. Department of Energy, 1980a).

Type	Number
Operations	449
Maintenance	342
Technical	103
Other	81
Supervisory	185
TOTAL	1,160

Energy

A survey of mills indicated that approximately 30-40 kWh of electrical energy is required to process one ton of ore. The requirements vary mill by mill, of course, depending on such factors as how far the tailings must be pumped, etc. (Perkins, 1979).

Hydrocarbon needs vary widely mill-to-mill because of such variables as use of heat from a sulfuric acid plant, circuit design (roasting, drying, elevated temperature in leaching, etc.) and type of circuit. Table V-9 indicates fuel-oil resource needs for several of the most recently constructed and proposed mills. Most of the older mills use natural gas rather than fuel oil to supply process heat (New Mexico Health and Environ ment Department).

Tailings areas also require energy input for their operation. Table V-10 lists energy requirements for tailings disposal serving a mill of approximately 4,000-5,000 tons per day throughput.

Construction of tailings dams and mills is another area of energy demand. In their license application, Gulf has estimated that mill construction will require on the order of 75 kWh per day over the 18-month construction time. The total gasoline consumed is estimated at 55,000 gallons and diesel consumption is estimated at 490,000 gallons.

Chemical

Mills require chemicals for use in both the leaching and solvent extraction sections of the mill. Table V-11 includes the estimated chemical needs of the proposed Gulf mill. Table V-12 indicates the needs of some of the other mills in New Mexico.

Table V-9. Fuel Oil Needs (New Mexico Health and Environment Department).

Mill	Operator	Fuel Oil	Use
Church Rock	UNC	#6 fuel oil	1.47 gal/ton ore
Nose Rock	Phillips	#2 fuel oil	6.15 gal/ton ore
L Bar	Sohio	#2 fuel oil	2.07 gal/ton ore
Marquez	Bokum	#2 fuel oil	2.47 gal/ton
Mount Taylor	Gulf	#2 fuel oil	5.95 gal/ton

Table V-10. Projected Yearly Energy Requirements for Operation of the Tailings Retention Area of the Gulf Mill (New Mexico Health and Environment Department, Gulf license application).

Source	Quantity
Manpower	3,000 hrs
Diesel fuel	42,000 gals
Gasoline	1,700 gals
Lube oil	700 gals
Grease	500 lbs
Electricity for sump pumps	65,000 kwhr
Electricity for return water system	130,000 kwhr

Table V-11. Estimates of Resources Committed for the Proposed Gulf Mill (New Mexico Health and Environment Department, Gulf license application amendment, March 1979).

Item	Per Day		Per Year	
Electrical Energy	1.6×10^5	kWh	6×10^7	kWh
Water (Process)	1.1	Mg	374	Mg
Water (Potable and Sanitary)	4,375	gallons	1.6	Mg
Sulfuric Acid	300	tons	102,000	tons
Sodium Chlorate	34	tons	12,000	tons
Ammonia	3	tons	1,000	tons
Sodium Carbonate	34.8	tons	12,000	tons
Hydrogen Peroxide	3	tons	1,000	tons
Alamine 336	20	gallons	7,200	gallons
Isodecanol	40	gallons	13,600	gallons
Kerosene	600	gallons	0.2	Mg
Flocculant	1	ton	350	tons
Fuel Oil (No. 2)	25,000	gallons	8.4	Mg
Coarse Ore	4,200	tons	1.4×10^6	tons
Uranium	13	tons	4,400	tons
Manpower	126	man-days	126	man-years

Table V-12. Resource Needs of Three Licensed Mills in New Mexico (New Mexico Health and Environment Department).

Church Rock Mill (UNC) Resource Needs			L Bar Mill (Sohio) Resource Needs		
Item	Rate		Item	Rate	
ore	5,555	lbs/min	ore	1,500	tons/day
water	723	gals/min	water	550	gpm
H_2SO_4	153	lbs/min	H_2SO_4	11,000	gals/day
$NaClO_3$	3.89	lbs/min	sodium chlorate	3,300	lbs/day (40 percent solution)
flocculant	.42	lbs/min	flocculant	166	lbs/day
kerosene	.42	gals/min	kerosene	135	gals/day
amine	.06	lbs/min	amine	NA	
isodecanol	.22	lbs/min	isodecanol	NA	
NH_3	7.26	lbs/min	NH_3	3,900 - 5,200 lbs/day	
people	117				

Marquez (Bokum)

Item	Rate	
ore	2,200	tons/day
water	500	gpm
H_2SO_4	166	tons/day (93 percent H_2SO_4)
$NaClO_3$	11	tons/day (40 percent solution)
flocculant	462	lbs/day
kerosene	450	gals/day
amine	130	lbs/day
isodecanol	200	lbs/day
$(NH_4)_2SO_4$	1,500	lbs/day (average)
NaCl	6	tons/day
Na_2CO_3	7	tons/day
NH_3	1,093	lbs/day (average)
glue	220	lbs/day

Land

The land required for tailings disposal and decant ponds is given in Table V2 and V4. In addition, land is required for haulage roads, ore storage pads, and mill-process buildings and tanks. For example, the estimates for the Sohio mill at the time of mill license application were that a total of 1,300 acres would be disturbed (New Mexico Health and Environment Department).

LEGISLATION

Federal

During 1978, Public Law 95-604, "Uranium Mill Tailings Radiation Control Act of 1978", was passed. This law set up 1) a remedial action program for inactive tailings piles, 2) new licensing regulations and definitions, and 3) a study of designation of two mill tailings sites in New Mexico. Because of confusion in the language in the act it was uncertain whether both NRC (Nuclear Regulatory Commission) and an agreement state had licensing authority over mills in that state. Further legislation was therefore passed clarifying this point and giving Agreement States authority until November 1981, by which time agreement states must meet certain licensing requirements in order to remain an agreement state. The result of the study (item 3) was that the inactive mill tailings under discussion in New Mexico were located at active mills (Anaconda and UN-HP) and could not be designated in the Federal remedial program for abandoned tailings piles.

Further information on the designated Shiprock and Phillips piles is given in the section on inactive mills.

In March of 1980 EPA Office of Radition Programs issued a draft EIS, Remedial Action Standards for Inactive Uranium Processing Sites, and in April 1980, EPA issued proposed cleanup standards for inactive uranium processing sites. These proposals covered contamination of drinking water and waters of the United States (for both radionuclides and non radionuclides), limited radon emission to 2 pCi/m^2-sec from disposal sites, and set a 5 pCi/gm Ra-226 standard for cleanup of open lands and buildings
(U.S. Environmental Protection Agency, 1980; Nucleonics Week, April 1980).

On June 24, 1980, EPA issued underground injection control technical regulations. These regulations cover insitu leaching, mine-water recirculation, and tailings sands backfill and set requirements for state programs operated in lieu of EPA. Uranium in situ wells were classed as class III wells. Tailings sand backfill operations were classed as class V. The state has asked for clarification of mine-water injection wells for the purpose of recirculation but will consider them as class V unless otherwise notified. In all cases an inventory and information program is required (Water Pollution Control Bureau, personal communication, June 1980).

NRC (U.S. Nuclear Regulatory Commission) has also issued 40 CFR 190, which limits general exposure from mill emissions to 25 millirems, excluding radon and radon daughters, to any member of the general public. This limit goes into effect at the end of 1980.

The August 24, 1979 Federal Register published NRC proposed rules for uranium mill tailings licensing criteria relating to uranium mill tailings and construction of major plants. These proposals were made after completion of the draft generic impact statement.

State

On April 21, 1980 radiation protection regulations passed by the EIB (New Mexico Environmental Improvement Board) were filed. Changes from the previous regulations effecting uranium milling include requirements for: 1) viable tailings management alternatives including below-grade disposal and alternative sites, 2) no construction of a uranium mill until a license has been granted, 3) title to land which the tailings pile is located on must be transfered to the United States or state government at cessation of milling, and 4) the United States or state government or applicant must have title to the land before disposal of wastes can begin. If the State is to remain an agreement state, bonding requirements will have to be included in the regulations (New Mexico Environmental Improvement Division, April 1980).

TAXATION AND REVENUE

Revenue

Revenue from taxation of uranium includes both a severance tax and a resource exise-tax. Uranium severance-tax collections in New Mexico are shown in Table V-13 for 1973-1979. Uranium resource exise-tax collections for the same period are shown in Table V-14. There are also a conservation tax and property tax (New Mexico Taxation and Revenue Department, 1980).

Table V-13. Uranium Severance Tax Collections in New Mexico, 1973-1979 (New Mexico Taxation and Revenue Department).

Time Period (calendar years)	Total Sales (lbs U_3O_8)	Tax Due (Dollar)
1973	9,922,639	131,935
1974	10,797,712	162,179
1975	10,852,685	181,556
1976	12,434,876	259,737
1977	12,317,108	4,414,590
1978	16,518,959	17,975,488
1979	15,306,368	13,354,031

Table V-14. Uranium Resources Excise-Tax Collection in New Mexico, 1973-1979 (New Mexico Taxation and Revenue Department).

Calendar Year	Gross Value (dollars)	Tax Due (dollars)
1973	62,946,413	455,597
1974	70,971,418	517,797
1975	77,135,835	564,002
1976	163,627,799	1,182,966
1977	345,675,642	2,573,714
1978	420,933,093	3,143,628
1979	386,259,346	2,857,763

Recent Changes in Rate of Severance

The rate of taxation was changed for uranium by legislation enacted in 1977 and again by legislation enacted in 1980. The legislation of 1977 set new severance tax rates beginning July 1, 1977 in accordance with a step-rate table, based upon the sales price per pound of the U_3O_8 (yellowcake) recovered in the severed and saved or processed uranium. The taxable event is the sale, transportation, or consumption, whichever occurs first. The rate schedule was as follows:

If Taxable value per pound of U_3O_8 was:

Over	But Not Over	Tax Rate
$ 0	$ 5.00	1.0%
$ 5.00	$ 7.50	$0.05 plus 1.6% of excess over $5.00
$ 7.50	$10.00	$0.09 plus 2.0% of excess over $7.50
$10.00	$15.00	$0.14 plus 3.0% of excess over $10.00
$15.00	$20.00	$0.29 plus 4.0% of excess over $15.00
$20.00	$25.00	$0.49 plus 5.0% of excess over $20.00
$25.00	$30.00	$0.74 plus 7.0% of excess over $25.00
$30.00	$40.00	$1.09 plus 9.0% of excess over $30.00
$40.00	$50.00	$1.99 plus 12.5% of excess over $40.00
$50.00 and over		$3.24

There was also a surtax on uranium. Under Chapter 345, Laws of 1979, the surtax was calculated the same way as the surtax on coal; however, the surtax applied only to uranium with taxable values of $50 per lb or more. The surtax has had minimal effect upon revenues because relatively few sales occured at this price.

In addition, the uranium severance tax was (and is) affected by a "grandfather clause" which allows any bona fide arms length contracts to be registered with the New Mexico Taxation and Revenue Department (formally the Bureau of Revenue), which were entered into prior to January 1, 1977 by August 1, 1977. If a contract qualified, the tax rate is a flat percentage rate of 1.25 percent of the taxable value per pound rather than a rate determined on the step-rate table. The criteria for registration were: (1) a contract for sale of uranium entered into prior to January 1, 1977; and (2) the contract "...does not allow the taxpayer to obtain reimbursement for all of the additional taxes imposed..." by the step-rate table. "Grandfathering" shall terminate if the registered contract is or has been amended in any manner after January 1, 1977, and the effect of the amendment is to increase the price of the uranium or the total quantity to be sold under the contract. The Director of the New Mexico Revenue Division provided a system for the registration of such contracts. Severance taxes under "grandfathering" will terminate on December 31, 1984.

The severance tax is due on or before the 25th day of the month following the month in which the taxable event occurs. The 1980 legislature changed the step-rate to that shown in the following table:

New Step-Rate Table

If taxable value per pound of U_3O_8 is:

Over	But Not Over	The Tax Per Pound Shall Be:
\$ 0	\$ 5.00	2.0%
\$ 5.00	\$ 7.50	\$0.10 plus 4.0% of excess taxable value over \$ 5.00
\$ 7.50	\$10.00	\$0.20 plus 6.0% of excess taxable value over \$ 7.50
\$10.00	\$15.00	\$0.35 plus 7.0% of excess taxable value over \$10.00
\$15.00	\$20.00	\$0.70 plus 8.0% of excess taxable value over \$15.00
\$20.00	\$25.00	\$1.10 plus 9.0% of excess taxable value over \$20.00
\$25.00	\$30.00	\$1.55 plus 10.0% of excess taxable value over \$25.00
\$30.00	\$40.00	\$2.05 plus 11.0% of excess taxable value over \$30.00
\$40.00 and	over	\$3.15 plus 12.5% of excess taxable value over \$40.00

Sales under the "grandfather" clause of the 1977 act, however, continue to be subject to the special reduced rate of 1.25 percent. In addition, a temporary provision credit is allowed to be phased in during a 3-year period. For the fiscal year beginning July 1, 1980, the credit is in the amount of 50 percent of the tax due on the first 100,000 lbs of U_3O_8 severed by each severer. For the fiscal year beginning July 1, 1981, the credit is 50 percent of the tax dues on the first 75,000 lbs of U_3O_8 and for the following fiscal year, the 50 percent credit applies to the first 50,000 lbs of U_3O_8. The tax due date under the new legislation remains unchanged. The 1980 New Mexico Legislature passed a bill that will temporarily lower the uranium severance tax rate to percent of its taxable value as defined by the 1979 legislation. The lower tax rates are scheduled to expire in 198 .

PROJECTIONS

Mill Capacity

As can be seen from Table V-3, total licensed mill capacity is presently 24,360 tons per day. It may be some time, however, before the Bokum mill will achieve its licensed capability. In addition, if Church Rock continues 10 days of running at 2,500 tons per day and 4 days down, this effectively limits its production to an average of 1,786 tons per day. Present capacity of New Mexico mills is thus approximately 19,946 tons per day. Assumming that maintenance will require 23 weeks per year, yearly milling capacity is approximately 6,861,424 tons. Production for 1980 therefore, cannot exceed by any large extent the 1979 6.9 million tons processed, if for no other reason than milling capacity.

How much milling capacity can increase in the next 5 years is open to question. If the Marquez mill is finished, if Gulf builds its Mount Taylor mill, if Conoco constructs its mill, if UNC finds and utilizes a suitable tailings area, and if Phillips comes on stream with that mill, total capacity will reach 32,610 tons per day or 1.63 times the present capacity. There appears to be sufficient constraints on the completion of all these projects and their full operation while at the same time continuing full throughput at the existing mills such as to make it appear unlikely that this production will be achieved within the 5 year time period. Considering constraints on mine and mill construction and production, New Mexico active milling throughput in 1985 may be about 27,100 tons per day.

Predicting U_3O_8 output from the mills is more difficult than predicting mill capacity because ore grade and recovery efficiency must be considered. The trend towards milling lower grade ores may continue until Gulf begins to mill significant ore tonnage. Grade should stabilize and perhaps increase for a short time; however, because the higher cost lower-grade ores will have to be milled if all of New Mexico's reserves are recovered, the long-term trend is probably towards lower grades. The new ores may also be more refractory, and hence, recovery may drop. The prospects, in terms of mill capacity and available ore to mill, are therefore on the short term basis for a rather stable yearly mill throughput (with perhaps a slight increase) with U_3O_8 production increasing somewhat as Mount Taylor ores are milled.

Ion Enchange

Mine-water recirculation is expected to increase slightly in the next 5 years. Recovery from mill tailings decant water will probably increase and new in-situ projects will probably be developed; however, because these projects do not produce large amounts of U_3O_8 compared with production from conventionally mined and milled ore, these projects are not expected to have a large effect on total U_3O_8 output in New Mexico in the near future.

Summary

Because the New Mexico uranium industry has cut back on exploration and mine development, rapid expansion of the industry does not appear possible due to the long lead times required from exploration to production. If the reactors now under construction come on line as planned and if the U.S. uranium industry does not increase U_3O_8 production, a shortage of U_3O_8 could develop as early as the late 1980's if domestic sources are relied upon. Production projections for New Mexico are presented in Chapter VI along with current production analysis.

Editor's Notes- The Legislature enacted a bill in 1981 that lowers the taxable value to be reported for severed and saved uranium bearing material to sixty percent of the sales price per pound. The act is effective through June 30, 1984. On June 30, 1984, the taxable value to be reported reverts again to the full sales price per pound. The new step-rate table of 1980 shown above is applicable in either instance.

As this report goes to press, UNC(United Nuclear Corporation) had successfully demonstrated to the EID(Environmental Improvement Division) that contamination of underground waters at its Church Rock milling operation could be halted by intercept wells.

Milling operations have been halted at the Sohio L-Bar mill near Seboyeta due to lack of toll ore.

CHAPTER VI

CURRENT PRODUCTION AND PRODUCTION PROJECTIONS

Although the amount of uraniferous ore weighed and sampled by mills and buying stations in New Mexico continued to increase over previous years in 1979, uranium concentrate (U_3O_8) production declined compared with 1978 and New Mexico's share of total domestic U_3O_8 production dropped six percentage points to 40 percent (Arnold et al., 1980). A record 6,880,000 tons of ore was weighed and sampled in 1979, which represented an increase of 644,547 tons or a 10 percent increase over the previous year. Table VI-1 provides comparative production data for the past six (6) years.

The ore processed in 1979 contained 8,186 tons of U_3O_8 of which 7,420 tons was actually reported as production. The difference between the amount of U_3O_8 contained in the weighed ore and the amount reported as production is due to quantities of U_3O_8 which have been lost in the milling process as well as that amount which has been stockpiled for later blending and milling and thus is not reported as production. Production of U_3O_8 in 1979 represented a decline of 1,140 tons or 13 percent from 1978. Concen trate production in the period 1966 to 1979 is shown in table 28 and fig. VI-1. Table VI-1 lists the amount of U_3O_8 contained in the ore, and table VI-2 lists the actual production of U_3O_8. Fig. VI-1 compares cumulative U_3O_8 production in ore by state between 1963 and 1979.

Table VI-1. Uranium ore weighed and sampled by mills and buying stations in New Mexico, 1974-1979. U.S. Department of Energy's Grand Junction Office (GJO-100, 1980) erroneously reported 1979 ore weighed and sampled as 6,880,000 tons (W.L. Chenoweth, personal communication, August 1980; U.S. Energy Research and Development Administration, 1975, 1976, 1977; U.S. Department of Energy, 1978, 1979a, 1980a).

Year	Ore (tons)	U_3O_8 (tons)	Ore grade %	% of total U.S. U_3O_8 production
1974	2,997,000	5,400	0.180	43
1975	2,985,000	5,500	0.184	45
1976	3,401,000	6,500	0.191	46
1977	4,209,000	7,600	0.181	46
1978	6,262,000	9,400	0.151	47
1979	6,906,547	8,200	0.119	40

Despite a decline from 1978, New Mexico's 1979 uranium concentrate production was, nevertheless, greater than any previous year with the excep_ tion of 1978. The noteworthy change in production patterns from past years has been a significant decline in the percentage of total United States production. New Mexico's share of domestic production dropped from 46 percent in 1978 to 40 percent in 1979. This decline has resulted from a greater share of production from other states, particularly Texas, which has experienced an increase of (7) percent of domestic production. Wyoming's share of total production has remained about the same at 27 percent. New Mexico, however, has retained its first place ranking among uranium- producing states and only during 1973 when a prolonged labor strike adversely affected mining and milling has the state failed to lead in U_3O_8 production. Between 1966 and 1979, New Mexico has averaged 45 percent of United States production. Following New Mexico and Wyoming, the balance of production in 1979 comes from Arizona, California, Colorado, Florida, Texas, Utah, and Washington. Fig. VI-1 compares New Mexico's uranium concentrate production with Wyoming and total domestic production between 1963 and 1979. Fig. VI-2 shows domestic production by other areas from 1953-79 with the Grants Mineral Belt in New Mexico for comparison.

The decrease in concentrate production can be attributed to a combination of factors including a declining average ore grade, down at one major mill, and adjustment to a depressed uranium market. Since 1977, the average ore grade as a weight percentage of contained U_3O_8 has steadily declined in New Mexico. The average ore grade reported by the DOE (U.S. Department of Energy) as weighed and sampled at mills and buying stations in New Mexico during 1979 was 0.119 percent U_3O_8. This percentage represents a substantial decline from 0.150 percent U_3O_8 reported during 1978 and 0.181 percent reported during 1977. A large part of the decline in average ore grade from 1978 to 1979 can be attributed to a dilution effect from the milling of large stockpiles of low grade ore from Anaconda's Jackpile-Paguate mine at Laguna. Other factors that have tended to lower the average ore grade include the mining of lower grade ores as a response to relatively high market and contract prices of the recent past and ultimately, the overall lower grades of newer deposits being mined and developed today compared to those of the past. Ore-grade percentages for the past 6 years are presented in Table VI-2.

Table VI-2. Uranium-concentrate production as recovered from ore weighed and sampled in New Mexico, 1966-1979; concentrate production for 1973 was adversely affected due to a prolonged labor strike at Kerr-McGee that year (U.S. Department of Energy, 1980a).

Year	U_3O_8 (tons)	Percent of total U.S. production
1966	5,076	48
1967	5,933	53
1968	6,192	50
1969	5,993	51
1970	5,771	45
1971	5,305	43
1972	5,464	42
1973	4,634	35
1974	4,951	43
1975	5,191	45
1976	6,059	48
1977	6,780	45
1978	8,560	46
1979	7,420	40
Average		45

Figure VI-1. Cumulative U_3O_8 production by state, 1963-1979. "Others" include Arizona, California, Colorado, Florida, Texas, Utah, and Washington. (U.S. Department of Energy, 1980a; W.L. Chenoweth, personal communication, August 1980).

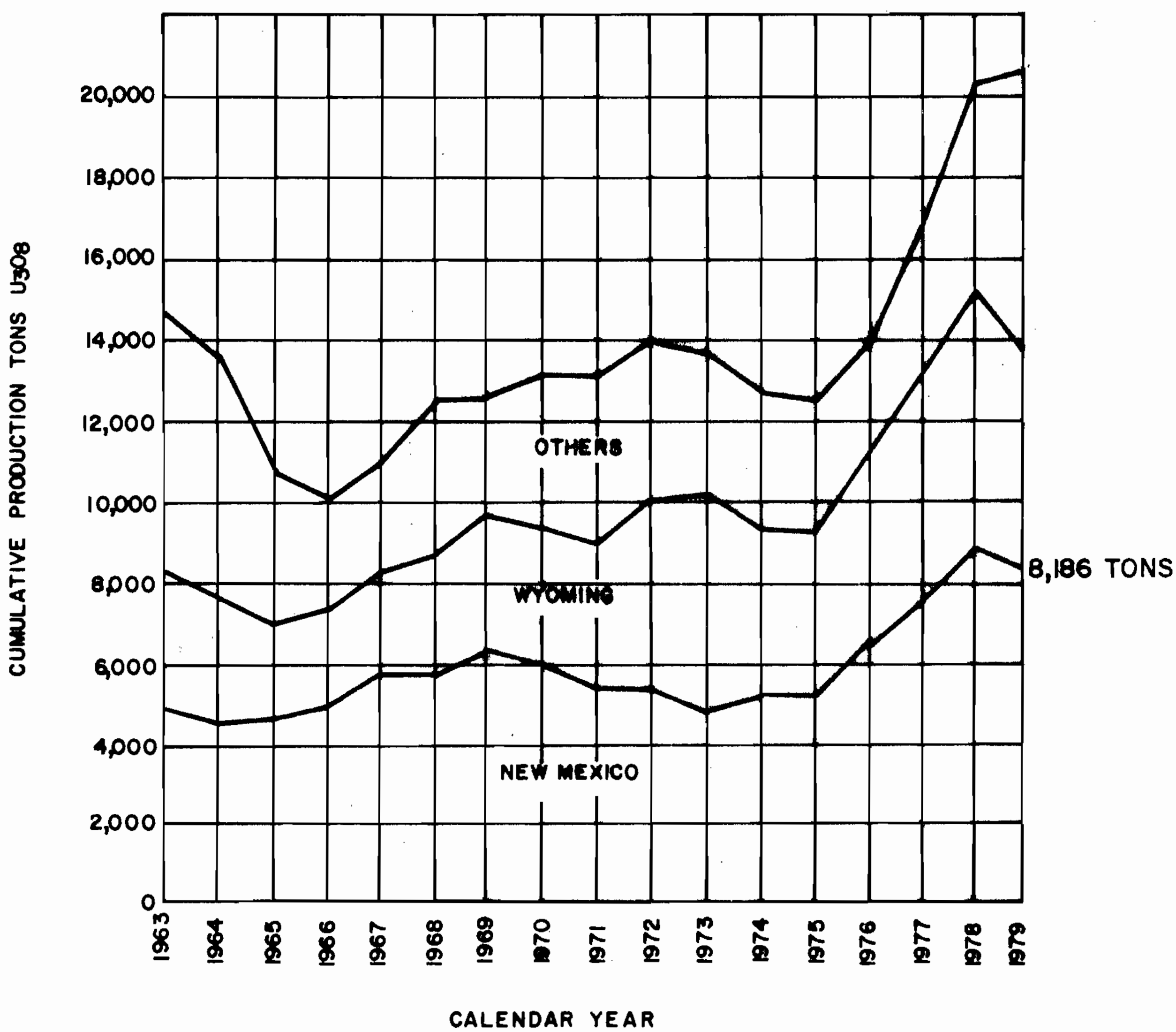
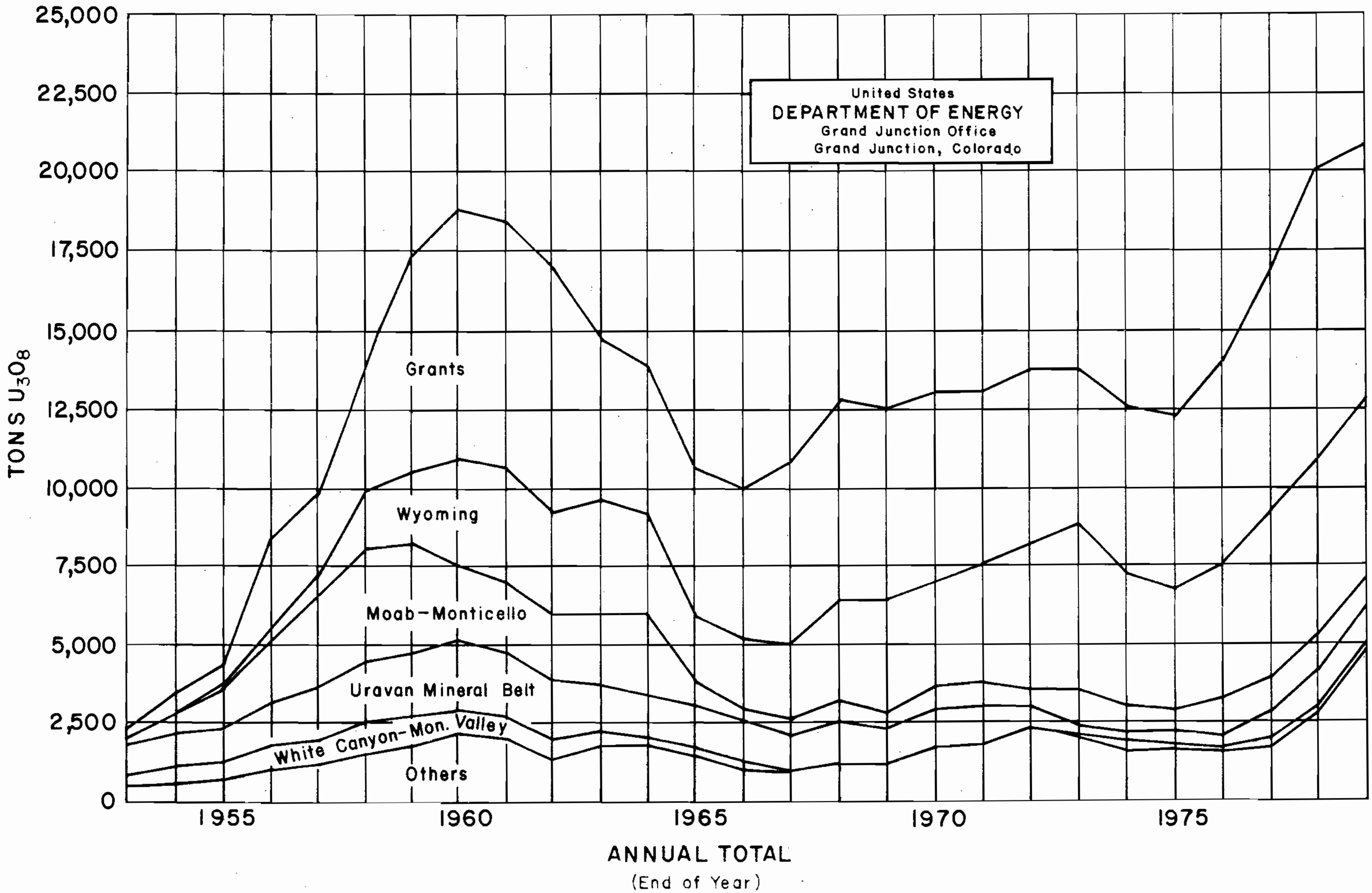


Figure VI-2. Uranium production from the Grants Mineral Belt compared to other major production areas in the United States between 1953-1979 (U.S. Department of Energy, 1980).



The most significant factor affecting production in 1979 resulted from a breached mill tailings dam at the United Nuclear Corporation Church Rock mill on July 16, which created a spill that resulted in the facility being out of operation for at least one hundred work days. Both milling and mining operations at the Church Rock facility were seriously disrupted for the balance of 1979 and into 1980. Mine closures and layoffs during 1980 are expected to create further production declines over the near future until significant new production comes on stream in 1982. The depressed domestic uranium market, according to industry, has adversely affected both production and development acting in conjunction with higher production costs and severance taxes, foreign competition, and uncertainties regarding future demand.

According to ore production data received from individual producers by the New Mexico Mining and Minerals Division, the Ambrosia Lake and Laguna mining districts accounted for the bulk of ore production during 1979. Anaconda, Kerr-McGee and United Nuclear are the three largest producers. Other mining districts reporting uranium ore production include Church Rock, Smith Lake, Chuska and Crownpoint. The Mount Taylor area is included with the Ambrosia Lake district so as not to reveal individual producers. Production percentages from Chuska and Crownpoint are treated similarly. The major production districts lie for the most part in Valencia and McKinley counties which account for the bulk of mine mouth production.

In 1979, uranium ore production from underground mines constituted almost 64 percent of total production. Open-pit mining contributed most of the balance. Eighty-three percent of New Mexico uranium ore production in 1979 was from depths of 1000 feet or less which, of course, includes all open-pit operations. Almost 17 percent came from underground production depths of 1000 to 2000 feet, and a minor quantity was reported from depths in excess of 2000 feet. Future production from ore bodies currently under development will come from depths in excess of 3000 feet. Sandstone and other clastic rock types accounted for approximately 98 percent of New Mexico ore production in 1979 with limestone production at about 2 percent of the total. The Jurassic Todilto Limestone is currently the production formation or host rock for all non-sandstone ore production in the state. Individual host rock units within the Morrison Formation of Jurassic age produced all of the sandstone ores with the Jackpile and Westwater containing the largest and most productive ore bodies. Ore production percentage during 1979, by various production categories are shown in Table VI-3.

Table VI-3. New Mexico ore production percentages by various categories for production year 1979 as calculated from production data submitted by individual producers to the Mining and Minerals Division; production percentages combined where necessary in order to protect the identity of individual properties (New Mexico Bureau of Geology).

1979 Uranium Ore Production % by Mining District

Church Rock	12.7
Smith Lake	3.3
Ambrosia Lake and Mt. Taylor	43.5
Laguna	40.1
Chuska and Crownpoint	less than 1.0

1979 Uranium Ore Production % by County

McKinley	59.6
Valencia	40.0
Sandoval and San Juan	less than 1.0

1979 Uranium Ore Production % by Mining Method

Underground	63.9
Open-pit	36.0
Other*	.1

*incl. in-situ, heap leach and mine-water recirculation/IX recovery

1979 Uranium Ore Production % by Mine Depth Range

0-1000 feet	83.0
1000-2000 feet	16.6
2000-3000 feet	less than 1.0

1979 Uranium Ore Production % by Host Rock

Westwater	53.5
Other Morrison (Brushy Basin, Recapture)	44.4
Morrison Total	97.9
Todilto	2.1

1979 Uranium Ore Production % by Host Rock Type

Sandstone and other clastics	97.8
Limestone	2.2

In terms of potential energy, the state's 1979 production, using conventional LWR (light water reactors), can be expected to yield approximately 3.4 quadrillion Btu (British thermal units) or the equivalent of 996 GWe (gigawatts electric) of electrical energy prior to transmission. The United States currently has about 61 GWe of generating capacity in operation of a total of 170 GWe in reactors which are ordered, under construction, or licensed to operate.

Production Projections

Current production projections of U_3O_8 (yellowcake) in New Mexico for calendar year 1980 as estimated by the U.S. Department of Energy are 7,770 tons or 36 percent of U.S. calendar year production (20,400 tons U_3O_8) (Jacobsen, 1980). Production data are collected from individual producers at regular reporting intervals throughout the year. Thus, New Mexico's share of total domestic uranium production appears to be declining steadily from a high of 48 percent of 1976 to 40 percent in 1979, and a projected 38 percent for 1980. Uranium production in New Mexico during 1980 will likely fall below current estimates if mine closures and market trends are any indication.

The New Mexico producers themselves have estimated that 1981 uranium production will decline further to approximately 6,115 tons, a drop of nearly 30 percent since 1978 when the state produced a record 8,560 tons U_3O_8 (Jacobsen, 1980).

Production projections from 1980-1985 are summarized on Table VI-4. Bureau of Geology projections indicate the probability of increased production beginning in 1982 when mines currently under development in the Crownpoint area begin to come on-stream, however, the current extremely adverse market situation may preclude or delay much of this new production.

Table VI-4. New Mexico uranium production projections from 1980-1985; from various sources as indicated (compiled by N.M. Bureau of Geology, 1980).

Year	Estimated Production (tons U_3O_8)	% of Total U.S.	Production Estimate Source
1980	7,770	36	U.S. Dept. of Energy
1981	6,000	--	N.M. Bur. of Geology
1982	6,300	--	N.M. Bur. of Geology
1983	7,000	--	N.M. Bur. of Geology
1984	7,200	--	N.M. Bur. of Geology
1985	8,200	--	N.M. Bur. of Geology

Editor's Note- As this report goes to press, the U.S. Department of Energy has reported that 1980 uranium production in New Mexico was 7750 tons U_3O_8. 1980 production as reported by uranium producers to the Mining and Minerals Division of EMD was 7407 tons U_3O_8 recovered from milled ore, virtually unchanged from 1979.

CHAPTER VII

RESERVES AND RESOURCES

Reserves

Reserves are the most reliable estimate of resources based on direct measurements of known deposits or their extensions. Reserves can thus be calculated for individual properties using radiometric and chemical data, drill-hole intercepts and other sampling data. Since 1948, industry reserve data have been voluntarily submitted on a confidential basis to the federal government agency mandated at the time to evaluate domestic uranium reserves, presently the Resource Division of the DOE (U.S. Department of Energy) in Grand Junction, Colorado. Reserve data that would reveal individual producers, however, is not available to the public since they are proprietary in nature.

Reserve estimates are published annually by the DOE for individual states as well as for geologic subdivisions provided that the reserve area does not identify individual properties. The estimates have traditionally been defined by forward-cost category which is the volume of uranium that can be expected to be produced at or below arbitrarily selected costs per pound of U_3O_8. The DOE considers their reserve estimates to be accurate to ± 10 percent. Ore reserve cost categories currently include estimates at \$30, \$50, and \$100 per lb. With 1979-1980 uranium market economics, the \$30 to \$50 per lb U_3O_8 forward-cost categories are considered to be the most realistic.

It is important to note that forward costs include operating and capital costs, in current dollars, that must be incurred by industry in order to produce a pound of U_3O_8. Such costs do not include labor, energy, materials, taxes, royalties, insurance, and administrative costs. Income taxes, profit, and the cost of financing are included. Sunk costs, which are all previous expenditures such as land acquisition, exploration, drilling, mine development, and mill construction, are not included. These costs must be retrieved over the life of the property through the sale of U_3O_8 concentrate.

New Mexico uranium reserves are shown in Table VII-1 which includes New Mexico's percentage of total United States' reserves in various forward-cost categories. New Mexico still holds a dominant position among all uranium-producing states in each of the forward-cost reserve categories, but because of higher costs, low prices, lower grades and depth considerations, the state's recoverable reserves may decrease compared to other states in the future. Melvin (1980) has made an analysis of the effect of severance taxation and royalties on producable reserves in the Grants region. The $30 per lb. reserve category will more than likely be dropped in estimates for 1981 and these reserves shifted to higher cost categories.

As can be seen in Table VII-2, New Mexico has more uranium reserves in the $50 per lb category than any one of the other producing states. New Mexico has 52 percent of domestic uranium reserves producible at $30 per lb, 48 percent of uranium reserves producible at $50 per lb, and 46 percent of uranium reserves at $100 per lb. In the $30 per lb range, 15 fewer properties are included for calendar year 1980 compared to 1979, resulting in a net decrease. This change would appear to indicate that after production, additional reserves are being defined only in extensions of known ore bodies rather than in newly discovered ore bodies. Table VII-1 shows reserve data for New Mexico in the various forward-cost categories from January 1978 through January 1980. Compared to calendar year 1978, when New Mexico held 52 percent of uranium reserves in the $50 per lb forward-cost category, the state now has 48 percent of all the United States uranium reserves in the $50 per lb category. Although six new deposits have been added to $50 per lb reserves, lower average grade and recent production depletion may account for the net decrease. Table VII-2 shows that New Mexico's reserves have declined while those of Wyoming and Texas have increased. New Mexico's reserves are in larger deposits, but must be produced at higher costs since they are at greater depths than those in Wyoming and Texas. Compared to the leading nations of the world in terms of reasonably assured uranium reserves at $50 per lb, New Mexico's reserves are exceeded only by the U.S. exclusive of New Mexico, South Africa and Australia. The current unfavorable market and production economics could, however, alter the state's reserve base in comparison to foreign producers. A comparison of international uranium reserves producible at $50 per lb is as follows:

Country	Tons U_3O_8 Reserves (1980)
Australia[1]	511,720
South Africa[1]	497,200
United States (excl. N.M.)[2]	487,300
NEW MEXICO[2]	448,700
Canada[1]	306,900
Niger[1]	214,500

[1] Source: NUEXCO, November 1980.
[2] Source: DOE, GJO-100 (80)

Table VII-1. New Mexico uranium reserves by cost categories, 1978-1980; \$15/lb forward-cost category dropped in 1979; \$100/lb forward-cost category added in 1979 (U.S. Department of Energy, 1978, 1979a, 1980a).

Forward cost category	Year	Tons ore	Percent U_3O_8	Tons U_3O_8	Percent of total U.S. reserves	Number of properties
\$15/lb	1978	111,300,000	0.20	222,000	60	106
	1979	85,700,000	0.22	190,900	66	89
	1980	Not included				
\$30/lb	1978	318,000,000	0.12	367,700	53	174
	1979	309,700,000	0.12	375,000	54	155
	1980	255,700,000	0.13	338,000	52	140
\$50/lb	1978	547,100,000	0.09	465,000	52	177
	1979	539,000,000	0.09	473,900	52	175
	1980	482,400,000	0.09	448,700	48	181
\$100/lb	1978	Not included				
	1979	Not included				
	1980	670,500,000	0.08	512,300	46	183

Table VII-2. Comparative distribution of domestic uranium reserves in the \$50/lb forward-cost category, January 1, 1979-January 1, 1980 (U.S. Department of Energy, 1979a, 1980a).

As of	State	Tons ore	Percent total % U_3O_8	No. Tons U_3O_8	U.S. (tons U_3O_8)	Properties
1/1/79	New Mexico	539,000,000	0.09	473,900	52	175
	Wyoming	504,100,000	0.06	287,300	31	276
	Texas	97,100,000	0.05	49,600	5	136
	Others*	159,800,000	0.07	109,200	12	1,225
1/1/80	New Mexico	482,400,000	0.09	448,700	48	181
	Wyoming	510,900,000	0.06	314,700	34	283
	Texas	104,400,000	0.05	55,800	6	135
	Others*	173,300,000	0.06	116,800	12	1,150

*Includes Alaska, Arizona, California, Colorado, Idaho, Montana, North Dakota Oregon, South Dakota, Utah and Washington.

Table VII-3 shows preproduction and postproduction inventories of U_3O_8 in New Mexico and indicates the grade ranges within which most of the state's reserves are included. Inventories are compiled by the DOE using company drilling data from individual properties. The preproduction inventories are cumulative tonnage-grade distributions of U_3O_8 prior to production; postproduction inventories represent in-place distributions of U_3O_8 after subtracting all production before January 1, 1980. Since all material that meets minimal mining thickness and is equal to or exceeds 0.01 percent U_3O_8 is inventoried, all postproduction inventories cannot be considered to be economically recoverable reserves; however, some 70 percent of New Mexico's current postproduction inventory may be considered recoverable at costs of \$50-per-lb or less. The balance of postproduction inventory at grades equal to or below 0.05 percent U_3O_8 must be produced at substantially higher costs, perhaps through improved technology as yet undeveloped.

Post production inventories of the state's uranium reserves are also important to illustrate how new reserves are added annually as production is subtracted. Both categories shown as cumulative tons of ore inventoried at or above minimum grades from 0.01 percent U_3O_8 to 0.25 percent U_3O_8 (Table VII-3).

The bulk of new reserves added in New Mexico comes from the San Juan Basin, either as new deposits developed basinward from the older known deposits or as extensions of the older deposits.

Ore grade

Ore grade is expressed as the percentage of U_3O_8 contained in a ton of uranium ore. New Mexico's sandstone deposits have typically averaged about 0.22 percent U_3O_8 although average production grade has been declining steadily so that the average was only 0.11 percent U_3O_8 for the 1979 production year. The national average is also 0.11 percent for 1979.

Table VII-1 also illustrates the important relationship of ore grade to forward-cost reserves. As can be seen, the number of new individual deposits that become available increase as the forward-cost increases, permitting economic recovery of uranium in the lower grade categories, More tons of rock must therefore be processed at higher costs to extract a pound of "yellowcake" or U_3O_8 concentrate. It should be noted that although New Mexico's uranium reserves are relatively high in comparison to other uranium producing states

Table VII-3. Preproduction and postproduction in New Mexico uranium inventory, January 1, 1980. Preproduction inventories of U_3O_8 are cumulative tonnage-grade distributions of individual properties prior to production. Postproduction inventories reflect in-place distributions of U_3O_8 after subtracting all production prior to January 1, 1980 (U.S. Department Of Energy, 1980a).

Minimum Grade (% U_3O_8)	Cumulative Tons of Ore (Millions)	Avg. Grade (% U_3O_8) of Cumulative Tons	Cumulative Tons U_3O_8 (Thousands)
PREPRODUCTION			
0.01	1,317	0.06	792
0.02	979	0.08	744
0.03	715	0.10	683
0.04	546	0.12	626
0.05	432	0.13	577
0.06	352	0.15	534
0.07	293	0.17	497
0.08	247	0.19	464
0.09	212	0.21	435
0.10	183	0.22	408
0.11	160	0.24	384
0.12	140	0.26	362
0.13	124	0.27	341
0.14	111	0.29	323
0.15	99	0.31	306
0.16	89	0.33	291
0.17	80	0.34	276
0.18	73	0.36	263
0.19	67	0.38	252
0.20	61	0.40	241
POSTPRODUCTION			
0.01	1,124	0.06	648
0.02	906	0.08	600
0.03	642	0.10	539
0.04	473	0.12	482
0.05	360	0.13	433
0.06	280	0.15	390
0.07	220	0.17	353
0.08	175	0.19	320
0.09	150	0.21	300
0.10	130	0.22	281
0.11	113	0.24	265
0.12	99	0.26	250
0.13	88	0.27	235
0.14	78	0.29	222
0.15	70	0.31	211
0.16	63	0.33	201
0.17	57	0.34	191
0.18	51	0.36	182
0.19	47	0.38	174
0.20	43	0.40	166

and nations, this position could be seriously eroded if production costs in New Mexico continue to increase with ever deeper, lower grade deposits. Only some new technology such as in situ solution mining may ultimately allow such deep deposits to be economically exploited and to compete with lower cost foreign and domestic deposits.

The Grand Junction Office of the DOE (U.S. Department of Energy) also publishes New Mexico $50 reserves as a function of grade, tons or ore, and numbers of property. A deposit may be divided amoung several ownerships or properties although many Grants Mineral Belt uranium deposits are one-ownership properties.

National reserves by cost category as of January 1, 1980, are shown in Table VII-4. During 1979 (1/80), reserves at $30 per lb actually decreased due to rising production costs thus making less uranium available at that price. Some 40,000 tons of U_3O_8 were added to the $30 per lb reserves from new discoveries and additions from extensions of known deposits. Due to inflationary costs, 66,000 tons were removed, and 19,000 tons were depleted through mining.

In the $50 per lb category, some 93,000 tons of U_3O_8 were added, including 64,000 tons U_3O_8 from new deposits and 29,000 tons U_3O_8 from additional reserves on know properties. Twenty thousand tons were mined and 57,000 tons were lost through cost increases, resulting in a net increase of some 16,000 tons U_3O_8 in the $50 per lb cost category. New Mexico contributed some 25,000 tons to $50 per lb reserves, but most of the net increase was from Wyoming. Reserves recoverable from solution mining (in-situ) as well as byproduct recovery (phosphates) are included in total domestic reserves.

Land status and location

New Mexico uranium reserves are located on private, federal, Indian, and state lands. Table VII-5 shows the $30, $50, and $100 per lb forward-cost reserves by mineral ownership. State lands hold only two percent of $50 per lb uranium reserves, Indian lands account for 18 percent; federal lands, 26 percent, and private lands had 54 percent of the state's $50 per lb uranium reserves.

Table VII-4. Historical national uranium reserves by cost category from 1/1/65 to 1/1/80 and changes in these reserves during 1979 (U.S. Department of Energy, 1980a).

As Of	\$15/lb Tons U_3O_8	\$30/lb Tons U_3O_8	\$50/lb Tons U_3O_8	\$100/lb Tons U_3O_8
1/1/65	-	-	-	-
1/1/66	-	-	-	-
1/1/67	-	-	-	-
1/1/68	248,000	-	-	-
1/1/69	265,000	-	-	-
1/1/70	317,000	-	-	-
1/1/71	391,000	-	-	-
1/1/72	520,000	-	-	-
1/1/73	520,000	-	-	-
1/1/74	520,000	634,000	-	-
1/1/75	420,000	600,000	-	-
1/1/76	430,000	640,000	-	-
1/1/77	410,000	680,000	840,000	-
1/1/78	370,000	690,000	890,000	-
1/1/79	290,000	690,000	920,000	-
1/1/80	225,000	645,000	936,000	1,122,000

CHANGES IN URANIUM RESERVES
During 1979

	\$15/lb U_3O_8	\$30/lb U_3O_8	\$50/lb U_3O_8
January 1, 1979 Reserves	290,000	690,000	920,000
New Properties	1,000	20,000	64,000
Reevaluation-Additions	0	20,000	29,000
Reevaluation-Subtractions	(52,000)	(66,000)	(57,000)
Depletion-Production*	(14,000)	(19,000)	(20,000)
January 1, 1980 Reserves	225,000	645,000	936,000

*Includes erosion, i.e., the amount of uranium-bearing material not recoverable in the future as a result of the mining of lower cost reserves in 1979.

Table VII-5. New Mexico \$30, \$50, and \$100 per lb forward-cost uranium reserves by mineral ownership during 1979 (U.S. Department of Energy, Grand Junction Office).

Land (Mineral) Ownership	Reserves (tons U_3O_8)		
	\$30 per lb.	\$50 per lb.	\$100 per lb.
Private*	189,400	243,100	267,900
Federal**	90,300	116,200	139,400
State	7,000	9,100	9,100
Indian	51,000	80,300	95,900
TOTAL	338,500	448,700	512,300

* include patented and homestead with no mineral rights reserved, land grants and railroad lands.

** include unpatented, homestead with mineral rights reserved and AEC withdrawn lands.

Potential resources

Resources include both reserves (defined resources) as well as potential resources (incompletely defined or as yet undiscovered). Potential resources, like reserves, are experssed in selected cost categories to cover the range of current economic interest. Unlike reserves, potential resources occur on undeveloped properties and their cost categories ($30, $50, and $100 per lb U_3O_8) must reflect front-end or sunk costs such as land acquisition, drilling, and development costs necessary to establish them as actual reserves. Potential resources, as a geologic endowment, are divided into three reliability categories: (1) probably, (2) possible, and (3) speculative.

1) Probable potential resources - those estimated to occur in know productive areas (i.g. Grants Mineral Belt) or their extensions.
2) Possible potential resources - those estimated to occur in undiscovered or partly defined deposits in formations or geologic settings productive elsewhere within the same geologic province or subprovince.
3) Speculative potential resources - those estimated to occur in undiscovered or partly defined geologic settings not previously productive or in geologic provinces or subprovinces not previously productive.

Standard methodology using geologic analogy

Geologists estimate potential uranium resources by applying geologic criteria of known deposits to geological formations or settings in unexplored or partly explored areas. Important geologic criteria include lithology, environment of deposition, rock alternation, geological structure and geochemistry, and perhaps known uranium occurrences. After a favorable host rock or area has been selected using these criteria, the quantity of uranium potentially contained within the geologic host or environment is estimated. Parameters include the volume of uranium-bearing rock per unit area, the average grade of mineralized rock in percent U_3O_8 at pre-selected cutoff grades, and finally the potential uranium resource in tons U_3O_8 (not tons of ore but tons of equivalent U_3O_8).

Estimates of New Mexico uranium resources

In New Mexico, potential uranium resources occur in at least 25 geologic formations distributed among four physiographic provinces. Table VII-6 shows probable, possible, and speculative New Mexico potential uranium resources by physiographic province, sub-province or area, geologic host rock, and volume U_3O_8. Figure VII1 shows the physiographic provinces and resource areas significant to uranium reserves and resources of New Mexico.

Potential resources are constantly being converted into known reserves as exploration drilling expands into frontier areas, thus, depletion of reserves through production is augmented to a degree by the addition of potential uranium resources. The percentage of 1968 potential resources in the United States and the Grants Mineral Belt that have been converted to reserves and production is shown in Table VII-7. The percentages of total resources that are considered potential resources are also shown in addition to cumulative production and reserves.

In New Mexico, host rocks in frontier areas not shown in table VII-8 that require further study, or that have received limited attention in the past are listed in Table VII-7.

Potential uranium resources in New Mexico occur in all of the state's four physiographic provinces including the Colorado Plateau, Basin and Range, Great Plains, and Southern Rocky Mountains.

The San Juan Basin of the Colorado Plateau province accounts for about 99 percent of the probable and possible uranium resources in the \$50 per lb U_3O_8 category, but for only about 2.5 percent of resources in the speculative category. This difference is an indication of the degree of exploration drilling in the plateau area compared to other geologic environments within the state. The second greatest potential for probable and possible deposits would appear to be in the northern portion of New Mexico's Basin and Range province, which embraces the Estancia and Hagan Basins between Albuquerque and Santa Fe where a deposit in the Galisteo Formation has been delineated within the past few years by Union Carbide. On the other hand, an area of speculative potential deposits appears to the the Great Plains province where little is as yet known from drilling and geological studies about the occurrence of uranium at numerous localities, some of which have recorded minor past production.

Figure VII-1. Physiographic provinces and resource areas significant to uranium reserves and resources in New Mexico (New Mexico Bureau of Geology).

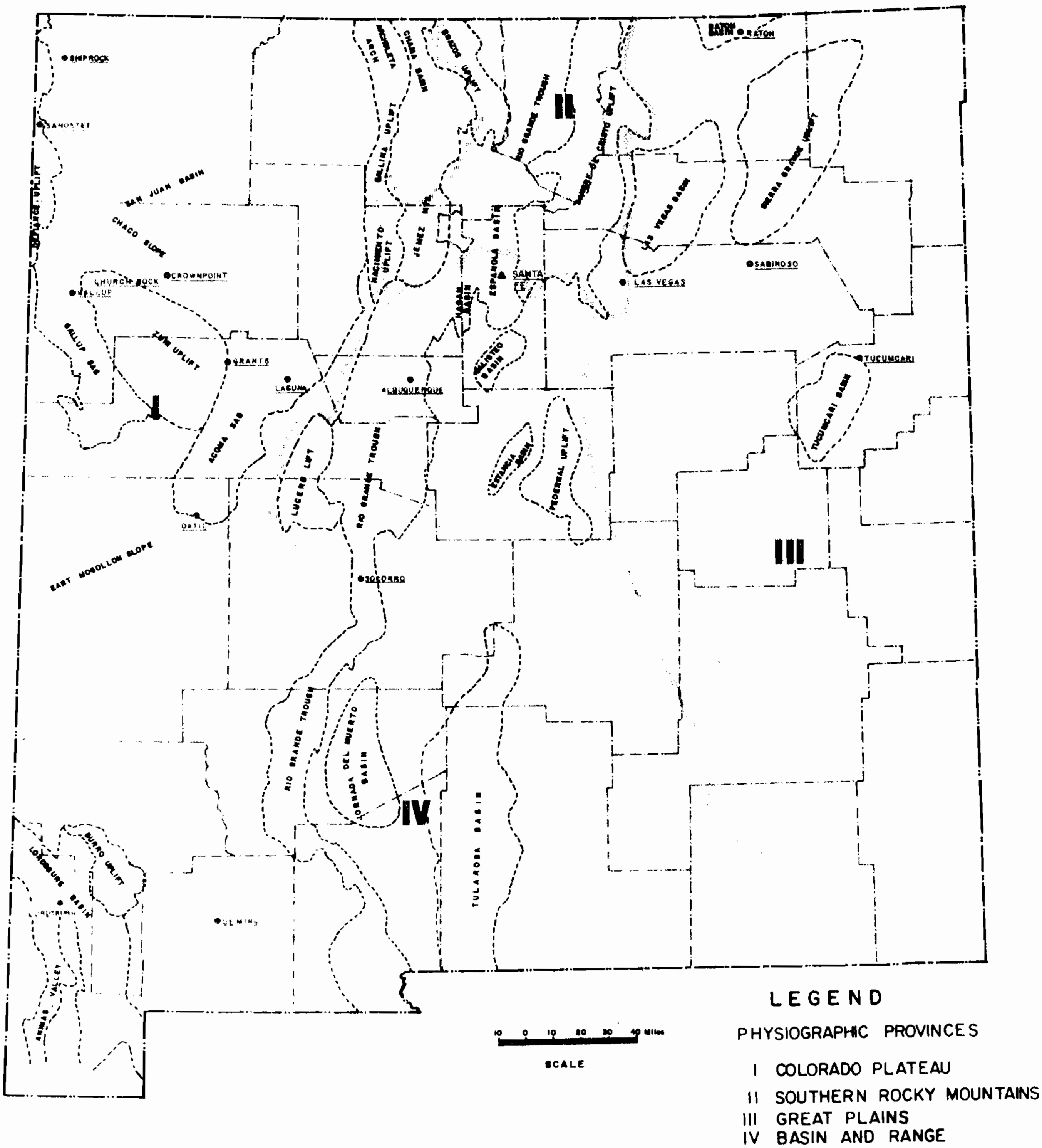


Table VII-6. Uranium resource areas of New Mexico showing type of occurrence or host rock by physiographic province and estimated potential resources (modified after U.S. Department of Energy, 1979b and 1980c).

RESOURCE AREA	Geology	*Potential Resources (tons U_3O_8)		
Physiographic Province & Tectonic Element	Host Rock	Probable	Possible	Speculative
Colorado Plateau				
San Juan Basin (Gallup Sag & Chaco Slope)	Dakota Brushy Basin			
Grants Mineral Belt (Chaco Slope)	Westwater Todilto	549,500	440,000	200
Chama Embayment	Burro Canyon			
E. San Juan Basin (Cuba-La Ventana)	Ojo Alamo			
East Magollon Slope (Red Basin)	Baca			
Total Colorado Plateau		549,500	440,000	200
Basin and Range				
Estancia, Galisteo and Hagan basins	Galisteo			
Rio Grande rift (Espanola Basin)	Tesuque			
Ladron Uplift	Popotosa			
Lordsburg & Animas Valleys	Basinfill (?)	500	1,000	500
Burro & Pedernal uplifts	Granitic rocks			
Jornado del Muerto Basin, Tularosa & Sierra Blanco basins	Palm Park Cub Mountain			
Total Basin and Range		500	1,000	500
Southern Rock Mountains				
Brazos and Sangre de Cristo uplifts	Pegmatites; granites	-	-	500
Gallina - Nacimiento Uplift	Chinle			
Total New Mexico Rockies		-	-	500
Great Plains				
Las Vegas Basin	Sangre de Cristo			
Tucumcari Basin	Chinle	-	-	7,000
Sierra Grande Uplift	Chinle Morrison			
Total Great Plains		-	-	7,000
Total New Mexico		550,000	441,000	8,000

Table VII-7. Uranium resources in the Grants Mineral Belt that have been converted to reserves and production from 1968 to 1980 (1/1/80) compared to the balance of U.S. (U.S. Department of Energy, 1980c).

Tons $U_3O_8 \times 10^3$

Year	Cumulative production & reserves		Potential Resources		Total Resources		% Potential resources in total resources		% of 1968 potential resources converted to reserves & production	
	US	GMB	US	GMB	US	GMB	US	GMB	US	GMB
1968	500	200	940	130	1,440	330	65	39	--	--
1972	650	265	1,650	680	2,300	945	72	72	16	50
1976	900	415	2,970	605	3,870	1,020	77	59	43	165
1980	1,480	600	2,550	290	4,030	890	63	32	104	320

Table VII-8. Potential uranium resource areas in New Mexico that require further study showing host rock, geologic age, and location by physiographic province (New Mexico Bureau of Geology).

Potential Resource Area	Host Rock	Geologic Age	Area
Colorado Plateau	Wasatch	Tertiary	San Juan Basin
	San Jose	Tertiary	San Juan Basin
	Fruitland	Cretaceous	San Juan Basin
	Menefee	Cretaceous	San Juan Basin
	Burro Canyon	Jurassic	Chama Basin
	Entrada	Jurassic	Chama Basin
	Agua Zarca (Chinle)	Triassic	Nacimiento Uplift
	Chinle undivided	Triassic	Chaco Slope
	Abo/Cutler	Permian	Nacimiento Uplift
Basin and Range	Gravel and alluvium	Quaternary	Hueco Mountains
	Santa Fe Group	Tertiary	Rio Grande Rift
	Thurman/Palm Park	Tertiary	Caballo Mountains
	Datil Volcanics	Tertiary	San Augustin Plains
	Espinaso Volcanics	Tertiary	La Bajada
	Cub Mountain	Tertiary	Sierra Blanco
	Chinle	Triassic	Southeast New Mexico
	Yates	Permian	Southeast New Mexico
	Gila Conglomerate	Quaternary-Tert.	Southwest New Mexico
Southern Rocky Mountains	Santa Fe Group	Tertiary	Espanola Basin
	Sangre de Cristo	Permo-Penn.	Sangre de Cristo Uplift
	Crystallines & Metamorphics	Precambrian	Brazos and Sangre de Cristo Uplifts
Great Plains	Gatuna	Quaternary	Lower Pecos River Valley
	Ogallala	Tertiary	High Plains & Llano Estacado
	Santa Rosa (Chinle)	Triassic	Tucumcari Basin, Sierra Grande Arch
	Chinle undivided	Triassic	Sierra Grande Arch, Pecos River Valley
	Sangre de Cristo	Permo-Penn.	Las Vegas Basin - Raton Basin
	Abo	Permian	Pecos River Valley

Accuracy of data

As is implicit in their definition, potential resources decrease in accuracy from probable to speculative. In order to improve the reliability of resource estimates, the U.S. Department of Energy is continually experimenting with new methodology, for instance, using computer-based geostatistical models.

Speculative probability using geologic analogy approaches to potential resource estimation have been tested in New Mexico for the San Juan Basin utilizing a representative sampling of geologists from industry, government, and academic fields (Ellis et al.,1976). It is interesting that the subjective probablity model results compared quite closely with that of a geostatistical Brink model down to 0.01 percent U_3O_8 grade range (Table VII-9). At grades of 0.01 percent U_3O_8 and below, the geostatistical model using crustal abundance calculations, indicated extremely large resources, whereas the geologists' probability model did not. Crustal abundance of uranium , unfortunately, includes tonnages that are contained within deeply buried veins or are disseminated within basement crystalline rocks, both occurrences not readily accessible as resources.

Table VII-9. Comparative estimates of New Mexico uranium resources showing the results of the subjective probability (geologic analogy) method to Brinck's crustal abundance geostatistical model (Harris, 1978).

	CUTOFF GRADE (% U_3O_8)			
	0.10		0.01	
	ROCK MATERIAL (SHORT TONS)	U_3O_8 (SHORT TONS)	ROCK MATERIAL (SHORT TONS)	U_3O_8 (SHORT TONS)
BASED ON:				
BRINCK MODEL	8.43×10^8	1.10×10^6	3.0×10^{12}	4.4×10^8
SUBJECTIVE PROBABILITY MODEL	6.09×10^8	1.26×10^6	3.8×10^9	1.4×10^6

NURE program

The purpose of the NURE (National Uranium and Resource Evaluation) program of the DOE is to acquire and compile geologic and other information to assess the magnitude and distribution of uranium resources and to determine areas of favorability for the occurrence of uranium in the United States. Contracts are awarded by DOE to various firms and institutions throughout the United States which have demonstrated or proven their ability to conduct these studies in a professional manner. New Mexico based institutions presently involved in NURE contract work include LANL (Los Alamos National Laboratory) of the University of California, Sandia Laboratories, New Mexico Bureau of Mines and Mineral Resources, and the University of New Mexico.

The NURE program strategy involves three successive work phases, including data collection, data evaluation, and, ultimately, resource assessment of each map quadrangle. Aerial radiometric surveys, hydrogeochemical and stream-sediment surveys, topical surveys, world class resource investigations, subsurface geologic investigations, technology application, and resource estimation methodology are among those newer activities which are being funded in the United States. ARMS (airborne radiometric and magnetic surveys) of 22 quadrangles that are shared with surrounding states were completed for the NURE program. The 1°-by-2° quadrangles of the NTMS (National Topographic Map Series) at a scale of 1:250,000 were the basic work unit. In addition, HSSR (Hydrogeochemical Stream Sediment Reconnaissance) and land status maps at this scale are being prepared for public release. Other data-gathering approaches used by the NURE program utilize geologic, geochemical, and geophysical methods in a more direct way, such as in the East Chaco Canyon drilling project. NURE projects are summarized in GJBX-11(80) (Bendix Field Engineering Corp., 1980c) entitled Annual Activity Report, dated March 1980.

The East Chaco Canyon drilling project of NURE consisted of 15 boreholes drilled in the Chaco Canyon area of the San Juan Basin for the purpose of obtaining subsurface data on possible basinward extensions of the mineralized Morrison Formation in the Crownpoint and Nose Rock areas. Of 15 holes drilled, four intercepted uranium mineralization at depths ranging from 3,975 to 4,670 feet. The mineralization was reported to be within both the Westwater Canyon and the Brushy Basin Members of the Morrison Formation. A total of 70,421 feet were drilled, and, of this total, 4,938 feet were cored. Lithologic and geophysical logs were taken of each drill hole, and a comprehensive study of the cores was made by the Geology Department of the University of New Mexico (Hicks and others, 1980). The conclusion of the drilling project has been that environments favorable for the occurrence of uranium exist for considerable distances basinward from known Grants Mineral Belt deposits. Data from the Chaco drilling project are presented in a report by the Bendix Field Engineering Corporation (1980b).

Editor's Notes- By act of the Legislature, a new county, Cibola County, was created effective in July 1981. Cibola County comprises what was formerly western Valencia County with Grants designated as the county seat. As far as can be ascertained, all uranium statistics cited in this report for Valencia County will be applicable to the newly created Cibola County.

CHAPTER VIII

DEMAND - PRODUCTION CONSIDERATIONS FOR NEW MEXICO'S URANIUM

This chapter will be divided into several sections covering the following topics:

1) historical forecasts and present trends in installed electric generating capacity

2) forecasts for uranium requirements

3) New Mexico's share of historical production

4) resource base for uranium

5) possible demand for New Mexico's uranium

6) reasons why production in New Mexico may not equal possible demand

7) the present situation in the uranium market

Using the information from international, DOE (U.S. Department of Energy), and private sources, it would appear to this author at the time of writing (August, 1980) that New Mexico's present uranium reserves or their equivalent from the resource base are totally committed for supplying uranium for the world's nuclear reactor program and that New Mexico's producers should expand production capacity within the next several years if an orderly development of nuclear power is to be achieved in the free world.

Historical Forecasts and Present Trends

Projecting demand for any resource has many possibilities for error; however, if reasonable planning is to be undertaken, it is helpful to make the best possible projections of what may be the demand for the resource in coming years.

In the case of energy consumption in the United States, historical demand projections now appear to have been too high. Many forecasters have assumed that growth in GNP (gross national product) was tied to a similar or higher rate of growth in energy consumption. Each year from 1973 to 1979, however, the energy/GNP ratio has declined. This decline is at least in part due to the rapid increase in energy prices in that period (EIA, 1980).

During the past decade, the annual rate of increase in total electrical generation averaged 4.8 percent. In their present projections, however the DOE's EIA (Energy Information Administration) is using an annual rate of 3.2 percent in 1980 and 2.8 percent in 1981.

Not only are utilities cutting back on construction of new facilities because of the reduced projected growth rate of electrical demand, but many United States utilities have been under severe financial constraints, and, in some cases, have not been able even to replace old units (Nucleonics Week, 1980). Thus, since nuclear energy is directly tied to generation of electricity in the non-military sector, cutbacks in the rate of construction of electric generating stations has meant that nuclear stations have not been constructed as quickly as was previously forecasted. In addition there have been the uncertainties due to the failure to resolve waste disposal problems in a timely manner. There are also the questions of safety, insurance, retrofit, etc., raised by the Three Mile Island accident. These issues have also caused utilities to delay committing to nuclear facilities.

For the long term, the question of rate of growth of usage of electric power is somewhat uncertain. While the ratio of total energy use to GNP is expected to continue to decline at least for a few years, it is not clear what the "energy mix" will be (World Energy Outlook, 1979). For example, industry and the domestic sector may switch from direct use of oil to electricity. Furthermore, the "energy mix" in the generation of electricity is also uncertain. Oil and gas-fired plants will certainly be phased out, but the rate of phase-out is again uncertain. Coal use may become unpopular if the harmful effects of acid rain and other environmental problems from burning coal become wide-spread or if transportation systems for coal cannot be built or are proven unreliable. Several cold winters when coal cannot be transported to generating stations could discourage its use.

Nuclear power stations may become more popular if meaningful steps to deal with spent fuel are taken, and the price of nuclear generated power is below that of coal. On the other hand, if spent fuel cannot be disposed of by utilities, if licensing or construction becomes too expensive, or if severe accidents occur, utilities will probably decide against construction of new nuclear stations. Political decisions to limit use of certain fuels could also influence the energy-use mix.

There is also a question of the rate of growth internationally of nuclear energy. Several nations, however, have already undertaken an aggressive pro-nuclear program, primarily due to their lack of alternative sources of energy. While some countries outside the United States are reprocessing spent fuel and moving toward commercial breeder-reactor technology, it appears that reprocessing and the use of breeders will not have a major effect on uranium consumption in nuclear power generation worldwide for at least the remainder of the century (Organization for Economic Cooperation and Development, 1979).

The EIA (Energy Information Administration) publishes a report to Congress each year. The reader should refer to this publication for more information from the federal government on forecasting, rate of energy growth, and energy mix.

Requirement Forecasts for Uranium

Requirements for uranium can be considered in several ways. Every year, DOE undertakes a marketing survey to determine both foreign and domestic sales commitments by United States uranium sellers and to determine buyers unfilled requirements. These numbers can then be combined to give United States yearly marketing demand as a function of year. Thus, "market demand" reflects procurement, inventory, and use practice of buyers and sellers. The 1979 survey results are shown in Table VIII-1 (Combs, 1979).

In addition to marketing demands, the actual yearly requirements can be forecasted by relating on-line nuclear generating capacity with such items as U-235 remaining in tails, fuel efficiency, and on-line generation time, etc. Nuclear fuel requirements are thus the physical quantitites minimally required to maintain the assumed nuclear power programs. Table VIII-2 indicates domestic yearly use demand as projected by EIA while Table VIII-3 indicates fuel demand as projected by NUEXCO (Nuclear Exchange Corporation), a private company.

Demand can also be considered in the context of total demand required to supply the needs of a reactor for its projected 30 year lifetime, or domestic reactor lifetime requirements. Table VIII-4 indicates several different projections for installed capacity in the United States, while Table VIII-5 indicates the present status of nuclear plants. These tables will be used in relating lifetime needs to the reserve base in one of the next sections.

Requirements for uranium should be projected not just in terms of domestic requirements but also as WOCA (World Outside Communist Areas) needs.

Table VIII-1. DOE Survey, marketing demand as of Jaunuary 1, 1979. In thousands of tons U_3O_8; (Combs, 1979).

Year of Delivery	Domestic Primary Sources to Domestic Buyers*	Domestic Origin to Foreign Buyers	Unfilled Requirements	Total
1979	19.1	2.6	.4	22.10
1980	20.0	1.6	1.1	22.70
1981	19.3	.8	3.3	23.40
1982	19.4	.5	4.2	24.10
1983	17.8	.5	5.6	23.90
1984	14.1	.4	9.5	24.00
1985	12.8	.4	12.0	25.20
1986	10.9	.25	14.9	26.05
1987	10.5	.25	17.0	27.75
1988	9.5	.25	20.3	30.05
1989	9.4	NA	23.7	33.10**
1990	7.3	NA	23.5	30.80**
1991-2000	19.3			

* includes optional quantities

** neglecting possible foreign sales

Table VIII-2. 1980 EIA Mid Case Projections of Future Yearly Milled Uranium Needs for the United States in Tons of U_3O_8[1]; (Clark, personal communication, August, 1980).

Year	Requirements for Milled Uranium
1979	14,325
1980	15,025
1981	15,552
1982	18,297
1983	20,524
1984	22,212
1985	22,962
1986	22,902
1987	24,252
1988	25,513
1989	25,811
1990	25,822
1995	30,484
2000	37,639
2005	44,930

1 0.2 percent tails assay

Table VIII-3. 1980 Nuexco Projections of Future Uranium Consumption for the United States in Million Pounds U_3O_8 Equivalent. Compiled and computed on a reactor-by-reactor basis, quantities for each reactor are based on specific core characteristics, 0.2 percent tails assay, no recycling, 24 month lead time for procuring first cores and 18 months for each reload, and individual reactor capacity factors estimated by NUEXCO (except 1979 when actual figures were used); (Nuclear Fuel, April 1980).

Year	Reactors Now Operational	Reactors Now Under Construction	Reactors Now On Order	Total U.S.
1979	16.3	8.5	0	24.8
1980	17.6	10.9	0	28.5
1981	17.7	19.7	0	37.4
1982	17.4	22.5	0	39.9
1983	17.9	24.6	2.0	44.4
1984	18.2	23.6	2.4	44.2
1985	18.4	23.1	4.8	46.4
1986	17.8	25.3	4.4	47.5
1987	18.3	25.5	4.3	48.1
1988	18.4	25.5	5.6	49.6
1989	18.3	25.2	7.8	51.3
1990	17.8	25.2	7.3	50.3

Table VIII-4. Midterm Nuclear Power Capacity in Commercial Operation: Comparison of Forecasts, 1985-1995 (Gigawatts at Year-end); (U.S. EIA, 1979).

Source	1985	1990	1995
1979 EIA Annual Report	86-109	121-139	137-160
1978 EIA Annual Report	102-118	142-171	186-225
1977 EIA Annual Report	100-122	157-192	-
DOE Utility Survey (January 1980)	122	169	177
Data Resources, Inc. (December 1979)	104	136	158
Pace (October 1979).	82	133	185
Exxon (December 1979)	123	146	177
National Electric Reliability Council (July 1979) .	134	-	-
CONAES (December 1979)	-	128-192	-
Nuclear Regulatory Commission	98	136	154
Westinghouse Corporation (March 1980)	103	142	192
Babcock & Wilcox, McDermott Corp. (March 1980) . . .	105	133	137

Table VIII-5. Status of United States Nuclear Powerplants as of March 31, 1980; (U.S. EIA, 1979).

Reactor Status	Boiling Water Reactors	Pressurized Water Reactors	Other*	Total Reactors	Net Megawatts Total Capacity
Operating**	26	42	3	71	52,200
Construction Permit Granted	28	60	0	88	96,700
10 Percent Complete or Better . . .	19	42	0	61	66,900
Less Than 10 Percent Complete . . .	6	11	0	17	19,300
No Construction	3	7	0	10	10,500
Under Construction Permit Review . . .	7	6	1	14	16,300
Order	0	3	0	3	3,500
Announced	0	0	0	0	0
Totals	61	111	4	176	168,700

* Includes one high-temperature gas-cooled reactor (Fort Saint Vrain), one liquid fast breeder reactor (Clinch River), and two DOE-owned reactors (Shippingport and Hanford N).

** Includes two DOE-owned reactors with a combined capacity of 940 MWe, Three Mile Island (906 MWe) which was shut down due to an accident in March 1979, and Humbolt Bay (65 MWe) which was shut down for seismic modifications.

Three tables are included to show the differences in range which various forecasters may have for WOCA yearly use requirements. Table VIII-6 shows OECD (Organization for Economic Cooperation and Development) projections, which may be somewhat high because of the manner in which they were obtained, while Table VIII-7 indicates EIA projections and Table VIII-8 gives NUEXCO projections.

Table VIII-9 lists projected WOCA nuclear generating capacity as a function of year for recent forecasts from OECD, Exxon, and EIA. Table VIII-10 indicates the present status of WOCA reactors.

Table VIII-6. OECD Uranium Yearly Use Requirement Projections for LWR Dominated Single Cycle Strategy; (OECD, 1979).

Year	Thousand Tons U_3O_8 Low	Thousand Tons U_3O_8 High
1980	37.70	41.4
1990	85.80	114.4
2000	176.8	258.7

Table VIII-7. 1979 EIA Projections for Uranium Consumption by WOCA Countries Using EIA Series C in Thousand Tons U_3O_8 Equivalent; (Clark and Reynolds, 1980).

Year	Total WOCA
1980	36
1985	51
1990	68
1995	85

Table VIII-8. 1980 NUEXCO Projections for Uranium Consumption by WOCA Countries in Million Pounds U_3O_8 Equivalent, compiled and computed on a reactor-by-reactor basis, quantities for each reactor are based on specific core characteristics, 0.2 percent tails assay, no recycling, 24 month lead time for first cores and 18 months for each reload; (Nuclear Fuel, April 1980).

Year	U.S.	Europe	Far East	Other	Total
1979	24.8	34.8	6.1	3.0	68.7
1980	28.5	29.6	7.8	3.7	69.6
1981	37.4	37.5	8.3	4.9	88.1
1982	39.9	37.9	12.1	6.5	96.4
1983	44.4	41.2	12.2	5.7	103.5
1984	44.2	42.8	11.5	8.7	107.2
1985	46.4	44.3	13.1	8.2	112.0
1986	47.5	41.2	12.4	7.9	109.0
1987	48.1	41.7	11.8	8.5	110.1
1988	49.6	42.1	12.3	8.5	112.5
1989	51.3	42.1	12.3	8.5	114.2
1990	50.3	42.1	12.3	8.8	113.5

Table VIII-9. Installed Nuclear Capacity as a Function of Year for WOCA Countries in GWe; (OECD, 1979; Exxon Corporation, 1979; Clark, personal communication, August 19, 1980).

Year	(Low-case) OECD	Exxon	EIA
1979	122.3		
1980	144.4		122.4
1981	163.0		140.6
1982	177.2		165.8
1983	199.8		183.2
1984	221.5		201.5
1985	257.1		221.9
1986	288.8		243.1
1987	324.4		261.9
1988	358.9		276.9
1989	397.2		292.3
1990	432.8	349	310.9
1995	616.8		406.7
2000	832.5	602	

Table VIII-10. World-wide Nuclear Power Status as of the end of 1979; (Atomic Industrial Forum, 1980).

Status	Reactors	Net MWe
Operable	166	70,200
Under Construction	156	125,364
On Order	33	27,472
Planned	233	224,003
Total	588	447,039

Historical Production - New Mexico's Share

As was discussed in a previous chapter, New Mexico's U_3O_8 production has historically averaged about 45 percent of total United States production. Production in 1979 dropped below this average partly due to loss of milling capacity when the United Nuclear Corporation tailings dam failed, and partly due to milling of some low grade ores (Hatchell, 1981).

Table VIII-11 indicates historical production in WOCA countries. This table shows New Mexico's share of WOCA production to be between 18-21 percent in the years 1975-1978.

Table VIII-11. Historical Uranium Production (Tons U_3O_8); (OECD, 1979).

Country	Pre 1975	1975	1976	1977	1978	Planned 1979
Argentina	361.4	28.6	52.0	130.0	163.8	240.5
Australia	10,140.0	0	466.7	462.8	670.8	780.0
Brazil	0	0	0	0	0	133.9
Canada	134,771.0	4,563.0	6,305.0	7,527.0	8,843.9	8,970.0
France	25,390.3	2,250.3	2,432.3	2,726.1	2,837.9	2,834.0
Gabon	7,082.4	1,040.0	NA	1,830.4	1,328.6	1,300.0
Germany	73.1	74.2	49.1	19.1	53.4	NA
Japan	42.9	3.9	2.6	3.9	2.6	NA
Mexico	54.6	0	0	0	NA	NA
Namibia	0	0	850.2	3,040.7	3,506.1	4,799.6
Niger	4,344.6	1,697.8	1,898.0	2,091.7	2,678.0	4,290.0
Portugal	2,247.7	149.5	114.4	123.5	127.4	110.5
South Africa	91,098.8	3,234.4	3,585.4	4,368.0	5,149.3	6,753.5
USA	248,300.0	11,600.0	12,747.0	14,940.0	18,490.0	18,730.0*
(New Mexico)		5,191.0	6,059.0	6,780.0	8,560.0	7,420.0*
Zaire	33,280.0	0	0	0	0	0
	557,407.8	24,788.5	28,716.7	37,507.2	44,070.1	
New Mexico / WOCA		.21	.21	.18	.19	

* actual

The Uranium Resource Base

There has been extensive exploration for uranium in some areas of the world while exploration in other areas has not been as intense. Based on the best available information, estimates of both United States and world uranium reserves (assured recoverable resources) have been made. The latest estimates for WOCA countries as published by OECD are indicated in Table VIII-12. New Mexico reserves as determined by DOE have been included to indicate New Mexico's position. It can be noted that New Mexico contains approximately 16 percent of the WOCA low cost less than $30 per lb U_3O_8 forward cost reserves and 14 percent of the less than $50 per lb U_3O_8 forward cost reserves.

Resources which are somewhat less assured than reserves have also been estimated for WOCA countries. In the United States these types of resources are referred to as potential resources and have been defined and discussed in Chapter VII.

The relationship of New Mexico's reserves and resources to total domestic reserves and resources has been discussed in Chapter VII.

Possible Demand for New Mexico's Uranium

Not only is it difficult to forecast total demand for a resource but it is even more difficult to forecast the demand which will be placed on a particular segment of the supply base.

As can be seen from the data presented in this report, New Mexico historically has had approximately 50 percent or more of total domestic low cost reserves, yet has produced on the average only 45 percent of the total domestic production. For WOCA countries, New Mexico has about 16 percent of the total reserves, yet production has been around 18-21 percent of WOCA production.

In order to make some sort of "first approximation" projections, however, the following will be assumed: (1) demand for New Mexico's uranium will be 45 percent of domestic marketing projections and 45 percent of U.S. uranium requirements, and (2) demand for New Mexico's uranium will be 16 percent of WOCA requirements. The results of making these assumptions are given in Tables VIII13 and VIII-14. While there is some range in demand projections in these tables, it can be seen that the New Mexico output of 7420 tons U_3O_8 in 1979 must be exceeded by 1982 or shortly thereafter if New Mexico is to produce its share of the WOCA needs (as reflected by the percentage of the WOCA resource base) and if the uranium stockpile is not depleted.

Table VIII-12. OECD Reasonably Assured Recoverable Resources (Corresponds to DOE Reserves) as of January 1, 1979 in Thousand Tons U_3O_8 Excluding USSR, Eastern Europe And China; (OECD, 1979).

Country	\$30 per lb U_3O_8 (or less)		\$30 \$50 per lb U_3O_8	Total \$50 per lb U_3O_8 (or less)	
Algeria	36.4		0	36.4	
Argentina	29.9		6.6	36.5	
Australia	377.0		11.7	388.7	
Austria	2.3		0	2.3	
Botswana	0		.5	.5	
Brazil	96.5		0	96.5	
Canada	279.5		26.0	305.5	
Central African Republic	23.4		0	23.4	
Denmark	0		35.1	35.1	
Finland	0		3.5	3.5	
France	51.5		20.4	71.9	
Gabon	48.1		0	48.1	
F.R. Germany	5.2		.6	5.8	
India	38.7		0	38.7	
Italy	0		1.6	1.6	
Japan	10.0		0	10.0	
Korea	0		5.7	5.7	
Mexico	7.8		0	7.8	
Namibia	152.1		20.8	172.9	
Niger	208.0		0	208.0	
Phillippines	.4		0	.4	
Portugal	8.7		1.9	10.7	
Somalia	0		8.6	8.6	
South Africa	321.1		187.2	508.3	
Spain	12.7		0	12.7	
Sweden	0		391.3	391.3	
Turkey	3.1		1.9	5.1	
USA	690.3		230.1	920.4	
(New Mexico)	375.0	(16% Total)	98.9	473.9	(14% Total)
Yugoslavia	5.8		2.6	8.4	
Zaire	2.3		0	2.3	
Total	2,405.0		962.0	3,367.0	

Table VIII-13. U.S. Uranium Requirements in Thousand Tons U_3O_8 Equivalent versus Possible New Mexico Demand; (DOE data: Combs, 1979; EIA data: Clark, personal communication, August 1980; NUEXCO data: *Nuclear Fuel*, 1980).

Year	1979 U.S. DOE Market Survey	N.M. Demand (45%)	1980 U.S. EIA	N.M. Demand (45%)	1980 U.S. NUEXCO	N.M. Demand (45%)
1979	22.1	9.95	14.3	6.4	12.4	5.8
1980	22.7	10.22	15.0	6.8	14.2	6.39
1981	23.4	10.53	15.5	7.0	18.7	8.42
1982	24.1	10.85	18.3	8.2	19.9	8.96
1983	23.9	10.76	20.5	9.2	22.2	9.99
1984	24.0	10.80	22.2	10.0	22.1	9.95
1985	25.2	11.34	23.0	10.4	23.2	10.44
1986	26.05	11.72	23.0	10.4	21.8	9.81
1987	27.75	12.49	24.2	10.9	22.1	9.95
1988	30.05	13.52	25.5	11.5	24.8	11.16
1989	33.10	14.90	25.8	11.6	25.6	11.52
1990	30.80	13.86	25.8	11.6	25.1	11.30

Table VIII-14. WOCA Uranium Consumption in Thousand Tons U_3O_8 Equivalent versus Possible New Mexico Demand Using Various Forecaster's Projections; (OECD, 1979; EIA data: Clark and Reynolds, 1980; NUEXCO data: Nuclear Fuel, 1980).

Year	Low OECD	N.M. Demand (16%)	EIA	N.M. Demand (16%)	NUEXCO	N.M. Demand (16%)
1979	41.6	6.66	36	5.76	34.3	5.49
1980					34.8	5.57
1981					44.1	7.06
1982					48.2	7.71
1983					51.7	8.27
1984					53.6	8.58
1985	48.0	7.68	51	8.16	56.0	8.96
1986					54.5	8.72
1987					55.1	8.82
1988					56.2	8.99
1989					57.1	9.14
1990	114.4	18.30	68	10.88	56.7	9.07
1995			85	13.60		
2000	258.7	41.39				

Demand can also be considered for the lifetime requirements of a reactor. While various assumptions such as fuel utilization, U-235 in enrichment tails, and on-line generating time must be made, the 30 year lifetime supply needs of a LWR's (light-water reactor) are approximately 5500 tons U_3O_8 equivalent per/GWe (gigawatts electric). The reserve base as of January 1, 1980 of $50 per lb forward cost reserves (936,000 tons U_3O_8) therefore, represents 170 GWe capacity of 30 year lifetime needs. If probable resources in the January 1, 1980 $50 per/lb. or less category are included (1,505,000 tons U_3O_8) a supply base for an additional 273 GWe of capacity would be available for a total of 443 GWe. Referring back to the projections for installed United States capacity (Table VIII-4), it would appear that, even for the least optimistic forecasts, all the $50 per lb or less forward cost reserves would be committed to supplying reactors installed by 1995 or soon thereafter. Resources would have to be converted to reserves if domestic reserves were to supply additional United States nuclear capacity.

Demand can similarly be considered for total installed capacity in WOCA countries. While not all WOCA reactors will be LWR's, a 30-year lifetime need of 5500 tons U_3O_8 per GWe will be assumed. Utilizing WOCA reserves in the $50 per lb forward-cost category (3,367,000 tons U_3O_8) indicates lifetime supply needs for 612 GWe. As indicated by the installed capacity projections listed in Table VIII-9, it appears that by 2000 or shortly thereafter WOCA reserves will only supply the lifetime requirements for reactors installed by that time. Thus even on a world-wide basis, New Mexico reserves may be committed to supplying existing facilities by 2000.

While some studies of uranium supply have indicated that 30-year lifetime reactor needs for those reactors installed past the year 2000 can be obtained from probable resources, it is not clear how much of the reserve and probable resource base will be available. While reserves are fairly well known, it does not necessarily mean they can be produced. There are many technical, financial, environmental, political, legal, and social constraints which may prevent complete recovery of the known reserve base. (this will be discussed more fully in a following section.) In addition, some probable resources may not be available when the attempt to convert them into reserves is made. <u>Thus, on the long term basis unless there are major discoveries not presently in the resource base or unless the world completely rejects nuclear energy, the world's supply of uranium appears to be of such a limited quantity as to indicate that attempts will be made to recover all reserves which can reason-</u>

ably be extracted including those in New Mexico.

Production Considerations in Relationship to Demand

While demand projections can be made, this does not mean that actual production will equal demand. There are many factors other than demand which determine production. Technical factors enter into determining production. Long lead times are necessary before a deep underground mine can be developed. In addition, a mine must be developed in an orderly sequence and this limits production at any one time. Ground control, geology of ore pods, need to dewater, and other technical considerations can also limit the rate of production.

Financial constraints may also delay timely production. Companies are unwilling to commit money to projects coming on line in the future unless these projects appear profitable. Confidence in the future of the industry and an orderly market are therefore factors influencing new projects. Financial constraints may also cause high-grading, a condition in which mining companies may be forced to remove only the higher grade ores if the price of the material declines. It is usually much more difficult to recover the lower grade material, or material in isolated small pods, if recovery is not carried out in an orderly manner. Because of high-grading, this material thus becomes even more expensive to mine and, in some cases, may be lost from the resource base.

Environmental considerations may also delay production. The need in some cases for environmental assessments, permits, and licenses may delay a project by several years. In some cases, environmental problems may be perceived as so severe that exploration, mining, or milling may be denied. Requirements for minimized contamination of the environment increase U_3O_8 production costs.

Political decisions can also cause delay and in some cases prevent U_3O_8 production.

Legal problems, such as obtaining control of the land on which tailing piles are to be located, and securing mineral rights, can cause delays. If a company has a mine adjacent to a small ore body held by another company, this ore body may not be recovered if the other company will not agree to having its ore body mined through the active mine even though the most economical access may be through the active mine.

Constraints such as the lack of trained miners, and the lack of access roads influence mining and milling.

Production, therefore,may not meet demand. As of August 1980, New Mexico active mills were generally running at full, available capacity. If an increase in U_3O_8 production in New Mexico is to occur, new facilities will have to come on line, the grade of ore fed to mills will have to increase, and/or New Mexico mills will have to increase available throughput. As of August 1, 1980, the Bokum mill had financing and ore-feed problems; the proposed Conoco mill needed siting studies, pre-license application monitoring, and other measures before submitting a license application; the proposed Gulf mill needed to resolve the land control problem and receive a discharge permit and license before beginning construction; and the proposed Phillips mill needed to submit alternative tailings disposal plans to the licensing group. Thus every new New Mexico mill at that time had potential delay problems.

Short-Term Uranium Supply

A comparison of uranium production and consumption in 1979 with previous years shows that production has exceeded consumption.

DOE publications indicate that there were 44,700 tons equivalent U_3O_8 held by uranium buyers (utilities, reactor manufacters, and fuel fabricators) in 1979. The 1979 market survey made by DOE indicated that 10 utilities out of the total 39 felt they had excessive uranium inventories. If the "market needs" for 1979 are compared with actual domestic production in 1979 (see previous tables) production did not meet "market needs" by approximately 3.4 thousand tons U_3O_8. What apparently happened was that some utilities changed their minds from the time of the initial survey; and, in addition, it is believed that some selling of uranium by utilities took place in 1979. There appears, therefore, to be a trend to reduce the level of stockpiles which had been originally indicated as desirable by the DOE market surveys.

DOE surveys also tried to determine the amount of U_3O_8 over and above current sales commitments that domestic producers estimate they will be able to offer for sale each year over the 1979 to 1985 period. Table VIII-15 indicates the results of the 1978 and 1979 surveys. The table shows that there was a drop of possible available uranium for sale from the 1978 to the 1979 survey. This decline may reflect a cutback in domestic producer expansion plans; nevertheless some U_3O_8 appears available for spot market sales from producers.

Table VIII-15. U_3O_8 Current Sales Commitments That Producers Estimate They Can Offer For Sale As Of January 1, 1978 and January 1, 1979; (Combs, 1979).

	Thousand Tons U_3O_8	
Year of Delivery	1/1/78	1/1/79
1979	4.1	1.4
1980	5.0	2.2
1981	8.2	4.0
1982	10.5	6.7
1983	14.0	8.4
1984	16.3	10.1
1985	16.9	10.5
Total	75.0	43.3

Because of their delay in bringing reactors on line and because short-term supply seems adequate, utilities in the United States have not been as aggressive recently in the market as they were in several previous years. This has been reflected in a rapid drop in the spot market price for uranium. Spot market prices at various times are shown in Table VIII-16. A great deal of uranium, however, is obtained by contract and Table VIII-17 indicates average contract prices.

Because of a weak spot market and other factors, domestic uranium producers are cutting back on expansion programs. From the NUEXCO projections for domestic consumption, it is apparent that if domestic producers do not expand production and if foreign imports do not exceed exports, utilities must begin to draw from the uranium stockpile by 1982 creating a 2-year stockpile by 1986. When considering domestic production versus domestic consumption, domestic producers must expand production by the mid to late 1980's and continue that expansion in later years if domestic needs are to be met primarily by domestic producers.

There are some suggestions that foreign uranium could make up the shortfall in domestic requirements. South Africa, Australia, and Canada are among those major countries which have excess capacity; however, as was indicated in previous sections of this report, projected WOCA reactor lifetime-needs by 2000 will commit all of WOCA's present reserves. Over the long term, it appears that excess capacity in WOCA countries should go to filling the needs of other WOCA countries outside the United States.

Table VIII-16. NUEXCO Exchange value for Uranium in the United States in \$/lb U_3O_8 1968-1980; exchange value is the company's judgment of the price at which sales of significant quantities of yellowcake could be concluded as of the reporting date: NUEXCO, 1980; Nuclear Fuel, 1980a,b,& c).

Date		Value
Dec.	1968	6.50
Dec.	1969	6.20
Dec.	1970	6.15
Dec.	1971	5.95
Dec.	1972	5.95
Dec.	1973	7.00
Dec.	1974	15.00
Dec.	1975	35.00
Dec.	1976	41.00
Dec.	1977	43.20
Dec.	1978	43.25
Dec.	1979	40.75
Feb.	1980	38.00
April	1980	32.00
June	1980	31.50
Dec.	1980	28.00

Table VIII-17 Average Contract Prices, Year-of-Delivery in the United States (Dollars); includes price settlements of market price contracts; (Combs, 1979).

	As of January 1, 1979		As of July 1, 1979	
Year	Price Per Pound of U_3O_8	Coverage of prices (%)	Price Per Pound of U_3O_8	Coverage of prices (%)
1979	18.95	92	21.60	94
1980	20.15	91	22.65	89
1981	24.60	87	30.10	86
1982	24.85	85	29.15	84
1983	26.05	83	30.15	82
1984	28.05	86	30.85	87
1985	28.95	84	33.65	86
1986	32.10	74	35.70	76
1987	34.25	75	37.65	77
1988	40.05	71	42.75	80
1989	-	-	46.10	80

The present requirement of the Canadian government is that prices under uranium export contracts must conform to the principle of marketing at the prevailing world price to be negotiated annually or an escalating floor price, whichever is higher. Canada's policy, therefore, seems to be not to dump uranium below market prices (OECD, 1979).

Harry Oppenheimer, chairman of Anglo-American Corporation of South Africa, has indicated that South African producers will probably stockpile uranium, and it is unlikely that further uranium production plants or extensions to existing ones will be undertaken in South Africa until the middle to late 1980's (Nuclear Fuel, July 1980).

The OECD 1979 report indicates a projected uncommitted surplus for Australia at around 5000 tons U_3O_8 yearly by the mid-1980's. Government decisions could reduce this surplus. NUEXCO projections show a WOCA demand of 56,000 tons U_3O_8 equivalent in 1985 so that 5000 tons represents about 9 percent of WOCA requirements.

While it may be possible, assuming optimistic production schedules, for WOCA countries other than the United States over the near term to dump uranium on the market and further disrupt it, this does not appear to be likely.

CHAPTER IX

SOCIOECONOMIC OVERVIEW

Introduction

The positive and adverse social and economic impacts which may accompany large-scale energy development projects are well documented in the body of literature which has evolved over the past decade.[1] The intent of this chapter is to present an overview of key economic and social issues in McKinley County and western Valencia County where New Mexico's uranium activity is concentrated.[2] Where possible, this chapter addresses these issues as they relate directly to uranium development; however, given the multi-industry base of the area, uranium-related socio-economic impacts cannot always be identified and addressed in isolation from those connected with other energy developments.

Employment

Table IX-1 presents uranium employment in New Mexico by county from 1969 through August 1980. Employment for 1969-1979 was taken from the New Mexico Bureau of Mine Inspection annual reports and therefore does not include exploration employees. The 1980 estimate was based upon 1979 employment adjusted to reflect the recent reductions in the work force. The basis for this adjustment included examination of current mine reports made by the Bureau of Mine Inspection, review of pertinent literature (e.g., newspapers, industry, and state and federal government publications) and discussions with knowledgeable industry and state officals. Given the current state of flux of the industry, post-1979 employment estimates should be frequently updated.

As seen in Table IX-1, McKinley County has consistently accounted for the largest portion of uranium employment in the state with almost twice the employment level of Valencia County, the other primary center of uranium activity.

Since the initial discovery of uranium near Grants (Valencia County) in 1950, production and consequently employment have fluctuated, reaching record levels in 1960 but dropping suddenly when the AEC (Atomic Energy Commission) announced the phasing out of its domestic uranium procurement program. In 1967, activity was revived with a growing number of plans for nuclear gener-

Table IX-1

Number of Employees by County

New Mexico Uranium Mines and Mills

COUNTIES

Year	McKinley	San Juan	Sandoval	Valencia	Total	% change from previous year
1969	1,783	2	-	519	2,304	
1970	1,863	2	-	727	2,592	+13
1971	1,459	2	-	778	2,239	-14
1972	1,133	-	-	791	1,924	-14
1973	1,012	4	-	855	1,871	- 3
1974	1,698	-	-	990	2,688	+44
1975	2,192	-	-	1204	3,396	+26
1976	2,953	4	-	1652	4,609	+36
1977	3,886	5	44	1958	5,893	+28
1978	4,101	5	55	2273	6,434	+ 9
1979	4,574	6	55	2689	7,324	+14
1980 (est.)	3,660	6	-	2349	6,015	-18

Source: New Mexico Bureau of Mine Inspection annual reports

ating facilities.[3] The cyclical pattern continued into the 1970's. The AEC's government procurement program was phased out in 1970, and the industry's market was then relegated solely to the private sector. Employment declined by 14 percent in 1971 from its 1970 level and 14 percent again in 1972. By 1974, the utility market for uranium had improved, and employment in this sector showed a strong gain of 44 percent in 1974 from a total of 1,871 in 1973. This high, annual growth rate continued through 1977 (ranging from 26 to 36 percent) and at a more moderate level in 1978 and 1979 (9 and 14 percent respectively). As of December 31, 1979, the New Mexico uranium industry reached a record high of 7,324 employees, marking a 218 percent increase over the 1969 employment level. In addition, an estimated 758 persons were employed in the uranium exploration industry in New Mexico during 1979.[4]

During the first 6 months of 1980, the uranium industry clearly showed signs of declining again. As of August 1980, at least eight operations were completely shut down, another six operations were reduced from three 8-hour shifts to one or two shifts, and several additional mines were idle.[5]

The Anaconda Company (subsidiary of Atlantic Richfield) announced in July 1980 it would be phasing out its open-pit Jackpile - Paguate mining complex; thus, 401 employees are expected to be laid off in February 1981.[6] As of December 1980, estimates for reduction in employment in 1980 ranged from 1300 to 1800 employees. The former estimate, which will be assumed in this chapter, takes into account idle operations and reductions in shifts in addition to those operations which have been shut down entirely, but this employment estimate does not include independent-exploration and service employment.

Another indicator of recent employment trends in the uranium industry is the number of unemployment compensation claims filed. According to the Grants and Gallup district offices of the New Mexico State Employment Services Division, the number of initial claims have approximately doubled during the first 6 months of 1980 compared with the last 6 months of 1979. The monthly breakdown of claims for western Valencia and McKinley Counties is as follows:

	Western Valencia County	McKinley County
1979		
July	39	107
August	30	115
September	27	82
October	84	87
November	106	87
December	74	160
Totals	360	638
1980		
January	152	183
February	98	141
March	92	252
April	115	273
May	109	176
June	204	219
Totals	770	1244

Income

Changes in the employment level are reflected in corresponding changes in income associated with uranium development. Both can cause indirect and/or induced changes in virtually every other sector of the local and regional economies. For example, decreases in uranium-linked industries, such as drilling and well-logging companies and mine-equipment suppliers, may occur with the decline in uranium development. A lower level of salaries and capital expenditures invested in the local economy by the uranium and supportlinked industries would correspondingly lead to induced changes, such as decreased purchasing power and lower economic activity including adverse effects on supporting (nonbasic) jobs.

Current statistics illustrate potential effects from changes in employment and income in New Mexico's uranium sector. In the fourth quarter of 1979, total wages in the uranium sector of McKinley and Valencia counties totaled $44,843,140.[7] In addition wage rates for many uranium industry employees are substantially higher than those of the wage rates of local service and public employees. Consequently, income lost in this section would be felt more immediately in the region.

As of July 1980, base salaries for uranium mine and mill employees ranged from $1,108 per month to $1,572 per month.[8] Wage rates are significantly higher if fringe benefits, overtime, shift differentials, and negotiated relative pay per contract are considered. Assuming an average of this salary range of $1,340 per month and a layoff of 800 employees, direct income losses would amount to $1,072,000 for a 1 month period. Indirect income effects would produce a significantly higher figure,[9] as would wage rates incorporating the factors mentioned above.

Population

As shown in Table IX2, the populations of the two counties and primary communities have grown significantly since 1950, with a large proportion of this growth occurring after 1970. In terms of compounded annual rate of growth since 1970, the communities of Milan and Thoreau led the way with 5.4 percent, followed by Grants (5.1 percent), McKinley County (3.3 percent), Valencia County (3.1 percent), the western portion of Valencia County, where development is concentrated (2.8 percent), and the City of Gallup (2.4 percent) (Historic data for Crownpoint and San Mateo were unavailable).

The portion of growth that is a direct result of uranium development is difficult to determine without accurate information on uranium work force characteristics, such as family size, number of in-migrants, and place of residence, however, some indication may be gleaned in viewing Table IX-2 in conjunction with Table IX-1 (historic employment by county).

Projected employment for 1980 and 1990 is given in Table IX-3. According to these estimates, which include projected expansion of coal development in the area, McKinley County's population will increase to 22,400 persons while Valencia County will gain 17,900 new inhabitants by 1990. The implication of these projected increases is clear — local infrastructures (including medical facilities and other public services such as water, sewer and roads) will have to expand substantially if growth of this magnitude is to be absorbed.

Table IX-2

Populations of Counties and Major Communities in the Grants Mineral Belt, 1950-1980

County/Community	1950 Number of Inhabitants	Percent of County Total	1960 Number of Inhabitants	Percent of County Total	1970 a,e Number of Inhabitants	Percent of County Total	1977 b,c,d Percent of Inhabitants	Percent of County Total
MCKINLEY COUNTY	27,451		37,209		43,208		56,000 (1978)	
Crownpoint (U)	n.a.	-	n.a.	-	n.a.	-	3,500	6.0
Gallup (C)	9,133	33.3	14,089	37.9	14,596	33.8	18,500 (1980)	31.7
Prewitt (U)	n.a.	-	n.a.	-	n.a.	-	400	0.7
Thoreau (U)	n.a.	-	n.a.	-	500	1.2	720	1.2
VALENCIA COUNTY	22,481		39,085		40,539		49,900	
Western Valencia County[b]	5,025	22.4	22,939	58.7	20,088	49.6	24,400	49.9
Grants (C)	2,251	10.0	10,274	26.3	8,768	21.6	14,500	29.1
Milan (V)	n.a.	-	2,658	6.8	2,185	5.4	3,700	6.0
San Mateo (U)	n.a.	-	n.a.	-	n.a.	-	300 (1979)[f]	0.6

Notes: n.a., not available; in most years, data are not available until after incorporation
(U), unincorporated
(C), incorporated as city
(V), incorporated as village

Sources:
a. U.S. Department of Commerce, Bureau of the Census, Census of Population, 1950-1970, Number of Inhabitants, New Mexico, 1952, 1962, 1973.
b. Harbridge House, Inc., Socioeconomic Component (of the) Northwestern New Mexico Coal Development Environmental Statement, (U.S. Dept. of Interior, Albuquerque, N.M.), Tables 2-5 and 2-2, except for McKinley County (c) Gallup, Grants, and Milan (d) and Thoreau (e), as noted.
c. 1978 projected population as reported by McKinley County through the 1980 Community Assistance Program application.
d. 1980 projected populations as reported by Gallup, Grants, and Milan through the 1980 Community Assistance Program application.
e. Thoreau's 1970 population as estimated by McKinley Area Council of Government's staff.
f. San Mateo's 1979 population as estimated by the Environmental Improvement Division's Milan Field Office.

Table IX-3

Projected Rate of Population Growth, 1980-1990[1]

	1980	1990	1980 - 1990 Additional Growth	Ranking Compounded Annual Rate of Growth
Prewitt	550	850	300	4.4%
Crownpoint	4,800	7,000	2,200	3.8%
Thoreau	1,700	2,450	750	3.8%
Milan	4,200	5,900	1,700	3.4%
McKinley County[2]	61,500	83,900	22,400	3.2%
Valencia County [2]	55,200	73,100	17,900	2.8%
Grants	13,500	17,600	4,100	2.7%
Gallup	20,150	24,550	4,400	2.0%
San Mateo[3]	300	not available	-	-

1 Projections from the Bureau of Land Management's Final Star Lake - Bisti Regional Coal Environmental Statement, February 1979, pp. II - 121-124 (Future Environment Without the Proposed Action).

2 Projections for McKinley and Valencia Counties based upon Bureau of Business and Economic Research's Population Estimates and Projections 1970-2000 for Counties and Wastewater Facility Planning Areas, September 1979.

3 Population as estimated by the Environmental Improvement Division's Milan Field Office as of August 1979.

Public Finance

The development of uranium resources in Valencia and McKinley Counties has had major impacts on public finance and public services. While the local jurisdictions hosting uranium development have benefited from an increased tax base, the need for public expenditures continues to outstrip incoming revenues. The thrust of this section, therefore, is to describe briefly the major issues which influence the fiscal condition of local governments in the study area.

In 1979, the total tax burden on the uranium industry amounted to $21,278,000. The breakdown is as follows:[10]

Tax	Amount (thousands)
Severance	$14,354
Resource Excise	2,858
Ad Valorem[11]	3,486
Conservation	157
Continued Care Fund	1,423
TOTAL TAXES	$21,278

Of this amount, only the ad valorem portion can be levied and directly appropriated on a local level (i.e., the tax is ordinarily levied by school districts, counties, the state, and cities, which benefit in that order).

Since no uranium mining or milling occurs within city limits, city governments receive no property tax revenue from uranium production. The remaining taxes paid by the uranium industry go directly to the state where they are then appropriated by the Legislature through approved legislation. Thus, while the uranium industry does contribute substantially to the tax base, it is primarily the state, not the local jurisdictions, which receives the greatest direct benefits.

Local governments in New Mexico have only two tax options available to them as effective sources of revenue. These are the ad valorem or property taxes which can be levied by both municipal and county governments and the gross receipts tax which can be levied by municipalities.

Municipalities can borrow money through bonds, but use of these revenues is restricted by the Legislature to capital improvements. The two basic types of bonds available are general obligation bonds and revenue bonds. General obligation bonds are further categorized into general purpose bonds and water and sewer bonds. The amount of general purpose bonds which can be issued is limited to 4 percent of the local jurisdiction's assessed valuation, while the amount of water/sewer bonds is unlimited.

The issuance of general obligation bonds requires voter approval and, for this reason, the proposed public works project being financed must be selected carefully in consideration of what will best serve the general citizenry. Counties must be particularly selective since they serve areas with different needs and interests. Counties normally utilize this source of revenue for financing public facilities, such as hospitals, courthouses, and jails, which will benefit the total county populace rather than only part of the population. Some small communities with a low assessed valuation have found that it is not cost effective to utilize general obligation bonds because of the expense of holding an election. Other municipalities, including Grants and Milan have been successful in using this mechanism to its maximum legal limit.

Revenue bonds do not require voter approval but are restricted to municipal or county-owned utilities (consequently, no counties in the state have issued utility revenue bonds to date). Unlike general obligation bonds, revenue bond issues have no legal limit but are calculated by what the system can reasonably pay back. The Legislature recently approved the issuing of industrial revenue bonds by local jurisdictions. These bonds are issued, with council or commission action, for new businesses locating in the area. The benefits are accrued in a larger economic and tax base.

In addition to the statutory constraints noted, local jurisdictions in the uranium belt are further restricted by localized institutional and political issues. Valencia County is administratively split into eastern and western portions, of which the economic base and public sector demands are significantly different. One result is the inability to pass any general obligation bonds. While McKinley County is free from this particular problem, it is a checkerboard area with two-thirds of the land owned by Indians and just 15 percent of the County privately owned.[13] Not only has this landownership pattern raised serious problems in the area of taxation, but also in law enforcement, highway construction, education, and other areas of governmental responsibility. The need to reassess property values in Valencia and McKinley counties has been prevented thus far by political and other considerations. At the municipal level, jurisdictional mismatches between those municipalities receiving revenue increases and those confronted with increases in demands for services almost always create problems in energy development. For example, Grants in Valencia County is the home of employees of many McKinley County activities including the United Nuclear Corporation and United Nulear-Homestake Parners' Ambrosia Lake mines, Kerr-McGee's Ambrosia Lake mill and mines, the Rancher's Exploration Johnny M mine, and the Gulf Mt. Taylor mine.

Local jurisdictions are limited by statutory, institutional, political and other constraints in their ability to generate the level of revenues needed to accommodate rapid energy-related growth. In Fiscal Year' 79-80, the General Fund receipts for selected jurisdictions were as follows: McKinley County, $1,825,244, City of Gallup, $6,824,631, Valencia County, $2,569,606 and City of Grants, $1,958,355.[14]

There are positive as well as negative aspects of the public finance picture. State and federal governments are aware of the many public finance constraints and have responded with programs designed to help mitigate the impacts. In particular, the New Mexico Community Assistance Program and the federal Section 601 Program are designed exclusively to assist energy-impacted communities. Industry, too, has responded to varying degrees with the provision of in-kind services and financial contributions for capital improvement projects. As the growth of expenditures[15] continues to outstrip the growth of locally generated revenues, the continued cooperation of these various parties -at-interest will be essential for a growing population and expanding industrial sector in the Grants Mineral Belt.

Housing and Commercial Development

In times of rapid growth, the private sector of the local economy suffers many of the same problems as the public sector. Specifically, the private sector may not be able to keep up with the demand due to such factors as financing, land and labor availability, and the condition of the community infrastructure (e.g., water, sewer, and utilities).

This department's recent assessment of private-sector impacts in Valencia and McKinley Counties reveals a slightly different situation from what was occurring 2 or 3 years ago. In particular, housing and commercial development, while still comparatively healthy, has leveled off from previous record levels. The value of residential building permits for March 1980 had fallen 66 percent in Gallup and 25 percent in Grants below the March 1979 level while the value of nonresidential permits showed a 234 percent gain in Gallup and dropped 18 percent in Grants.[16]

Speculative housing construction is still proceeding in Grants but on a smaller scale and often on a wait-and-see basis. Extensive land development, including a 307-acre Gulf subdivision in Grants, is planned or already under way and will help enable the city to meet new housing demand as the economy picks up; however, water and sewer improvements are a prerequisite if projected growth is to be accommodated in Grants.

The City of Gallup, the other primary trade center in the study area, is also experiencing some leveling off of new housing and business starts as evidenced by the value of building permits. At present, there are four new residential developments under way, ranging from custom-built homes to townhouse units to apartment construction.[17] Rental units including home spaces remain very tight and would indicate a continuation of a high proportion of temporary residents.

Currently, there is a moderate supply of conventional single-family homes on the market, which will increase as new housing developments are completed, however, City officials believe this supply will be absorbed over the next few years in accordance with projected growth rates. Like Grants, the City of Gallup must expand its infrastructure if growth in its population and economic base is to continue. Water supply is the short-term issue with the development of a new, firm water source as the long-range objective.

The factors influencing the recent downturn in residential and commercial development (particularly in Grants, and to a lesser degree in Gallup) are fairly self-evident. The nation is in a recessionary period, with federal policies designed to curb inflation through higher interest rates on loans, among other selected strategies. The local economy is feeling these pressures and, in addition, the effects of an uncertain uranium market. The combination of these factors is reflected in the inability and/or reluctance of private and commercial investors to commit large amounts of capital into a new business or homes during a period of economic instability. Certainly the magnitude and duration of the downturn in the private sector will be determined by the state of the economy and, more specifically, by the actions of the uranium and other mineral extractive industries (such as coal and gas) in the area.

Social Impacts

Social impacts as used here are meant to include social, cultural, demographic, and political changes in the communities hosting uranium development. These changes include varying degrees and types of impacts to such diverse parties-at-interest as industry and local business; local, state, and federal governmental entities; "old timer" residents, and other affected parties.

The area encompassed by Valencia and McKinley Counties is rich in its cultural heritage and diversity. In McKinley County, the Indian population predominates (62 percent), followed by Anglos (26 percent) and Hispanics (11 percent). The Anglo and Hispanic populations are roughly equal in Valencia County (85 percent) with the remaining 15 percent being Indian.[18] This diversity makes it virtually impossible to generalize as to the nature of potential social impacts, unlike more homogeneous energy-impacted communities such as Meeker, Colorado or Douglas, Wyoming; however, some insight may be gained in reviewing the trends which have begun to emerge.

The recent development of uranium and other minerals in the area has resulted in the in-migration of Anglos and, to an extent, Navajo Indians who are returning to the reservation for new employment opportunities with the energy industry. With this change in migration patterns, a shift from an older population to a younger one is expected to continue.

Because the uranium industry's wages are significantly higher than in many other available sectors of the economy, the cost of living has risen, and the ability to retain local governmental and service employees has also become more difficult. (Conversely, the recent layoffs in the uranium industry have enabled the City of Gallup to rehire some of its former employees who had left to work in the mines and mill).[19] Elderly residents and others who live on fixed incomes are most directly and adversely affected by higher rents, taxes, etc.

The range of changes discussed thus far is not unique to the study area, but has been duplicated in other communities experiencing rapid growth from the development of large-scale projects. The uniqueness of the area lies in its cultural differences, which are particularly important considerations when uranium development involves Indian and Hispanic populations. A thorough identification and analysis of these differences are beyond the scope of an overview; however, they are very important considerations in future relationships among cultural groups and with the uranium companies.

Conclusions

The intent of this chapter has been to provide an overview of the historic and potential socio-economic impacts from uranium development. The recent downturn in the uranium industry clearly has important implications for the social and economic environment. Caution must be used, however, in interpreting the magnitude and specific consequences of this event on the host locales. In particular, it is the net socio-economic impact which is of primary importance but which remains extremely difficult to guage. Several factors must first be considered: 1) the reassignment of a laid-off employee to another operation within the corporation (in-state and out-of-state); 2) new employment with another uranium-producing company; 3) absorption of excess labor by other energy development projects in the area (e.g., construction and operation of the Plains Escalante Generating Station near Prewitt and/or expanding coal development); and 4) the portion of those workers with permanent residency elsewhere (e.g., Denver) with temporary assignments in northwestern New Mexico, or those who commute daily from Bernalillo County. The ability to respond to these factors requires a tracking system of employees who have been terminated; only then can the net impacts to the region be accurately assessed.

Editor's Notes- By act of the Legislature, a new county, Cibola County, was created effective in July 1981. Cibola County comprises what was formerly western Valencia County with Grants designated as the county seat. As far as can be ascertained, all uranium statistics cited in this report for Valencia County will be applicable to the newly created Cibola County.

FOOTNOTES

CHAPTER IX

1. One commonly referenced in-depth analysis of socio-economic impacts from the development of uranium and other mineral resources in New Mexico is the Governor's Energy Impact Task Force's Managing the Boom in Northwest New Mexico, September 1977. An update of this comprehensive document is in the planning process. A useful guide for identifying and assessing socio-economic impacts from uranium development is the Stone and Webster Engineering Corporation's Administrator's Guide for Siting and Operation of Uranium Mining and Milling Facilities, Chapter 5: Socio-economic Considerations, Chapter 5, prepared by the Denver Research Institute under subcontract to Stone & Webster for the Western Interstate Energy Board. Denver, Colorado: Stone & Webster Engineering Corporation; May 1978.

2. There is potential large-scale development of uranium in Sandoval & San Juan Counties. However, for the purpose of this chapter, the focus will remain on existing development and its related impacts.

3. Energy Impact Task Force, Managing the Boom in Northwest New Mexico, p. III-17.

4. U.S. Department of Energy, Statistical Data of the Uranium Industry, GJO-100(79), p. 79. Employment data for New Mexico was extrapolated from this table by GJO staff.

5. Staff analysis of data from recent industry reports and internal files.

6. Grants Beacon, July 11, 1980, p. 1, and the Employment Security Commission's Grants District Office.

7. Employment Security Commission, Series 202230, 6-23-80 for 4th Quarter 1979.

8. Occupational wage rates for mine and mill employees (excluding management and supervisory personnel) as reported by the Grants District Office of the Employment Security Commission.

9. For a detailed analysis of employment and income generated by the New Mexico uranium industry, see John P. Myers and Larry Adcock, "Direct and Indirect Economic Impact of the Uranium Industry in the San Juan Basin," (Working paper No. 46, San Juan Basin Regional Uranium Study), Albuquerque: July 1979.

10. New Mexico Taxation & Revenue Department's "Study of the Relative Levels of Taxation on Energy Minerals Extracted in New Mexico," Santa Fe: January 18, 1980. Also based on discussions with the New Mexico Oil & Gas Accounting Division.

11. 1979 ad valorem taxes are estimated on the basis of data for only six months during that calendar year due to the recent contesting of payment by several major uranium companies.

12. State Planning Division, 1980 New Mexico State Investment Strategy, (Prepared for the Section 601 Program) Santa Fe: 1979.

13. San Juan Basin Regional Uranium Study, Uranium Development in the San Juan Basin Basin Region, Albuquerque: U.S. Department of Interior, 1979, p. XI - 5.

14. Department of Finance & Administration, Local Government Division.

15. Facility needs for Gallup and McKinley County alone has been estimated at \$17.5 million over a five-year time frame. (McKinley Area Council of Governments, The Impact of Energy Development on Gallup & McKinley County, N.M. Gallup: September 1977.)

16. Bureau of Business and Economic Research, New Mexico Business, Vol. 33, No. 4, May 1980, p. 27.

17. Personal communication with Paul McCollum, City Manager of Gallup, August 1980.

18. San Juan Basin Regional Uranium Study, Uranium Development in the San Juan Basin Region, p. VII-4.

19. Personal communication with Paul McCollum, City Manager of Gallup, August 1980.

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CHAPTER X

ENVIRONMENTAL CONSIDERATIONS

This chapter will attempt to address the various environmental aspects associated with uranium production in New Mexico. A discussion of recent Federal and State legislation pertaining to environmental considerations is included in Chapter V - Uranium Milling and Recovery Operations.

GENERAL CONSIDERATIONS

Possible Exposure Pathways

Uranium production can transport toxic materials into the environment where the materials may cause adverse effects. An individual can (1) breathe in toxic particulates (including the radioactive particulate daughters of uranium) and gases, (2) ingest the materials either by drinking water containing the released toxic elements or by eating plants or animals which contain the toxic materials, or (3) be affected by the external radiation produced by the radioactive elements.

Present Assessment Situation

While baseline data gathering studies and modeling programs have recently been started (see sections on studies) because of the very incomplete data base, it is presently impossible to assess the effect uranium production may have on the health of the general population, now or in the coming years. Transport pathways, rates of movement, and quantities of toxic materials (which are the result of uranium production) in air, soil, water, plants, and animals in areas around production activities are not completely known. While progress has recently been made, there is also an inadequate data base on emission rates. The effects of low doses of radiation over long periods of time are also difficult to assess. However, most of the radioactive daughters of uranium have extremely low maximum permissible concentrations in air and water (as set by NRC, International Evaluation Groups, etc.). Other elements often associated with uranium ore can also be toxic in small quantities.

ENVIRONMENTAL ASPECTS OF URANIUM MINING IN NEW MEXICO

Emissions and Transport

One of the major radioactive emissions in uranium mining is the release of gaseous radon (Rn-222). This radionuclide is the decay product of Ra-226 and hence is one of the daughters in the U-238 decay chain. When ore (which represents a greater than background concentration of uranium and in most cases the daughters also) is mined, the opening up of the orebody allows some of the radon to diffuse into the mine. In wet mines, most of the radon contained in the water moving into the mining area is also released into the mine. Releases of radon during blasting and diffusion from waste and rubble piles in the mines are other sources for radon emissions during mining. In addition, in areas around the mine, radon diffuses from the ore storage piles and from waste disposal dumps containing Ra-226.

Releases of radon will be estimated for (1) New Mexico underground mines, (2) New Mexico surface mines and (3) waste disposal areas at abandoned mines in New Mexico.

A study is now in progress to determine radon emission from underground mines by the Battelle group of P.O. Jackson et al. In their latest publication (PNL-3262) they report, based on measured mine vent radon levels and estimates of emissions from other sources of radon at uranium mines, an average emission of 26.7 curies Rn-222/ton U_3O_8 mined.

While production data for New Mexico mines is proprietary, total U_3O_8 contained in total New Mexico ore production was approximately 8,186 tons in 1979. Of this the author has estimated that 5,230 tons came from underground and 2,946 tons came from pit mines. Use of the Battelle emission number indicates approximately 139,641 Ci/yr (curies per year) of radon were discharged from active underground mining operations in New Mexico in 1979.

New Mexico also has active pit mines. For these it was estimated that there were in 1979 approximately 3,000 acres of disturbed area (pits, ore piles and waste disposal areas) containing an average value of 0.04 percent U_3O_8 (Reynolds et al., 1976). Nielson et al. have indicated that a formula of 0.092 Ci/(M.yr. percent U_3O_8) estimates radon release from U_3O_8 containing surface materials. This formula would then give an estimated emission of 44,677 Ci/yr from pit mining in 1979.

To estimate emissions from abandoned waste disposal areas, the following approach was used. It is known that 216 properties had been or were in production in 1978 (U.S. Department of Energy, 1979a). Thirty-six of these were in active production in 1979 and have been included in estimates of emissions from active mines. Jackson et al. have estimated that 68 Ci/yr is the average Rn-222 emission from present mine waste disposal areas. Assuming inactive waste disposal areas (dispersion, which increases effective Rn-222 emission, has occurred in abandoned areas) have the same average as active areas, this would lead to an estimate of 12,240 Ci/yr Rn-222 from abandoned waste areas. In addition, abandoned pit areas and unflooded underground mines with open vents and shafts will also have radon emissions. While these emissions are not well known they could be significant. Table X-1 summarizes these estimates.

Table X-1

SOURCE	CURIES/YEAR
Underground mining operations	139,641
Pit mining operations	44,678
Abandoned waste disposal areas	12,240
Abandoned, unreclaimed pit areas	--
Abandoned, dry, underground mines open vents/shafts or collapsed areas	--

Mining activities can also release other radionuclides in addition to Rn-222. Radioactive particulates may become airborne due to blasting, loading of ore, and wind suspension of material from ore and waste piles. The radionuclides will include natural uranium, thorium-230, radium-226, lead and other daughters of uranium. No emission factors are presently available for radioactive particulate emissions from active and inactive mines.

Mining equipment and explosives emit non-radioactive particulates, sulfur and nitrogen oxides, carbon monoxide and organics. The total emissions of these types depend on type of equipment used, mining techniques, etc. In addition, haulage of ore to the mill also generates emissions from fuel combustion (and if roads are not paved, dust).

Discharge of mine water is another emission which may have an effect on the environment (New Mexico Health and Environment Department). This will not be discussed in detail as a comprehensive report on discharge rates and water quality discharged off site at New Mexico mines has been published by EID (Goad, 1980). However, continued monitoring with a determination of the individual radionuclide contained in the discharge is needed. Discharge rate of mine water per mine is expected to increase as new mines are developed at deeper levels.

Radon, because it is a gas, diffuses as a gas until it decays to its particulate daughter (Silker and Heasler, 1979). Modeling of atmospheric transport of radon and particulates has been undertaken; however, because of the poor emission data and inaccurate knowledge of atmospheric conditions these modeling studies may not indicate true ambient radon monitoring. The EID has undertaken an extensive program of ambient radon monitoring and the data should be published soon.

If buildings are built on top of Ra-226 contaminated areas, or if the material is used for fill for building structures, radon diffusion into tight buildings will cause high concentrations of radon daughters in the air of the building.

Resuspension of radioactive materials deposited on formerly barren ground can also occur, resulting in further movement of the toxic material.

Not only have gamma surveys of mine waste piles indicated above-background levels of gamma radiation, but preliminary surveys also indicate above background gamma levels at off-site regions, apparently at least in part due to wind and water transport of mine waste. The extent of this problem is unknown and warrants serious attention.

Radioactive materials and other toxic materials resulting from mining activities can either be originally placed or move into drainage areas so that surface water contamination and toxic material water transport is possible. This problem has not been adequately assessed (Kaufman et al., 1976). The State of New Mexico is aware of the problem and some studies are in progress. These (including water discharge impacts) are part of the study of the uranium industry's influence on ground and surface water quality. EID's staff indicate:

> "New Mexico's program under Section 208 of the federal Clean Water Act includes an area wide assessment of uranium industry

impacts on ground and surface water quality. This assessment is being done by EID staff, with installation and operation of surface gaging stations being done through an agreement with the United States Geological Survey (USGS).

The primary goal of the monitoring program is to document the extent to which contaminants from uranium industry sources migrate down surface watercourses and infiltrate shallow alluvial aquifers. The monitoring activities are to be expanded during 1980 to include a study of ground water impacts of runoff from uranium spoils and tailings piles.

During 1978 and 1979, fifteen ground water observation wells were installed by EID, and it is anticipated that 10 to 15 additional observation wells will be installed during 1980. These wells are sampled four times per year by EID staff. An interim report on monitoring well design, sampling regime and discussion of the initial sampling results is expected to be completed during 1980. This assessment project is expected to take five years to complete."

The toxic elements in the mine may be mobilized through oxidation processes allowing the element to become soluble if water flows into that area (as in mine water recirculation). Mining practices, such as backfill may also influence mobilization into the aquifer of soluble material originally contained in the backfill. Mobilization, rate of movement, sorption mechanisms, etc., need further study.

Pumping wet mines causes a cone of depression to occur. Inter-aquifer flows may result if there are connecting faults or fractures in the area. Connections between aquifers can also occur from shaft and vent failures. The transport of material between aquifers, due to inter-aquifer connections made by mining activities, has not been studied.

Plants are also a mechanism in the transport of toxic material. Plants grown in Ra-226 containing material appear to increase the rate of radon release. Plants also uptake and in some cases concentrate toxic elements. Toxic material may also be deposited (both by wind and water action) on leaf surfaces. Not only should the natural uranium and uranium daughters be considered but also Se, Mo, V, and As, which are often associated with uranium-bearing ores. When animals or humans eat these contaminated plants further transport occurs (Dreesen and Marple, 1979).

Other Effects

There are other lesser environmental effects from uranium mining. These include possible damage due to blasting at pit mines, if buildings are located nearby. The fans used to discharge mine air are noisy. There has been limited subsidence in some areas, however, this effect is not expected in the area of the newer, deeper mines. Ore trucks on public highways increase traffic and hence the probability for accidents.

Recent Studies

One of the most important programs which has recently been started is the evaluation of emissions from uranium mines. This program, in part being undertaken by the Battelle staff of Pacific Northwest Laboratory, has as its objective the development of a data base, characterization of emissions, study of atmospheric dispersion, deposition and transport and environmental assessment. At the present time the following studies have been published by Battelle on mine emissions:

Nielson, K.K. et al., Prediction of the Net Radon Emission from a Model Open Pit Uranium Mine, NUREG/CR 0628 Rev. PNL 2889, Battelle Pacific Northwest Laboratory, Richland, WA, 1979.

Jackson, P.O. et al., Radon - 222 Emissions in Ventilation Air Exhausted From Underground Uranium Mines, PNL - 2888 Rev. NUREG/CR - 0627, Battelle Pacific Northwest Laboratory, Richland, WA, 1979.

Jackson, P.O. et al., An Environmental Study of Active and Inactive Uranium Mines, Mills and Their Effluents, PNL - 3069, Battelle Pacific Northwest Laboratory, Richland, WA, 1980.

Jackson, P.O. et al., An Investigation of Radon - 222 Emissions From Underground Uranium Mines, PNL - 3262, NUREG/CR, - 1273 Battelle Pacific Northwest Laboratory, Richland, WA, 1980.

EPA has also recently published the results of a sampling program at the Jackpile. Ambient radon-222, working levels, airborne particulate radioactivity concentrations, gamma surveys, and radioactivity in food and water sample results are reported in:

Beard, Mala L., Eadie, Gregory G. and Fort, William C., Ambient Airborne Radioactivity Measurements in the Vicinity of the Jackpile Open Pit Uranium Mine, New Mexico, ORP/LV - 79 - 2, Office of Radiation Programs, Las Vegas Facility, Las Vegas, Nevada, January 1979.

EPA has also distributed a limited number of copies of a draft study:

> Blanchard, R.L. et al., Potential Health and Environmental Hazards of Uranium Mine Wastes, Draft, EPA Office of Radiation Programs, Washington, D.C., September 1979.

The staff at the Los Alamos National Laboratory has published studies of stabilization and plant uptake. These studies are included in the mill section in this Chapter, except for:

> Kelley, Nathan E., Vegetational Stabilization of Uranium Spoil Areas, Grants, New Mexico, LA - 7624 - T, LASL, Los Alamos, New Mexico, January 1979.

which includes a study of vegetation at the Jackpile-Paguate as well as plant uptake of toxic materials.

In addition, the EID regional monitoring study, which was mentioned in a previous section, has had two initial reports. These are State of New Mexico Water Quality Status Summary, New Mexico Water Quality Control Commission, May 1980, and the New Mexico Surface Impoundment Assessment, EID, February 1980. The EID has also just published Water Quality Data for Discharges From Uranium Mines and Mills in New Mexico.

Conclusion

While much more data is now available than when the first Overview of the New Mexico Uranium Industry was prepared, there are still major gaps in the data base. Basic data on emissions, comprehensive surveys of contaminated areas, knowledge of complex transport pathways and rates of movement, and dose assessment is lacking.

The long term effects due to mining are somewhat dependent upon whether present and future mining operations stabilize their waste piles, minimize toxic element discharge in mine water, rehabilitate pit and underground mines, and use mining techniques which minimize aquifer contamination.

On the short term, development of techniques for reducing radon emission from underground mines would reduce this major discharge.

ENVIRONMENTAL ASPECTS OF URANIUM MILLING IN NEW MEXICO

Emissions and Transport

Uranium mills have various types of non-radioactive emissions to the atmosphere. The use of hydrocarbon fuels causes production of combustion products that are usually emitted from stacks connected to the combustion equipment. Mills having a sulfuric acid plant will have emissions of sulfuric acid mist and other sulfur compounds. Sulfuric acid mist is also emitted from the leaching circuit. Some organics are emitted during solvent extraction. Use of efficient combustion equipment and scrubbers and mist eliminators, where applicable, reduce the airborne non-radioactive emissions from a mill to very low levels.

Radioactive emissions occur from a variety of sources. Radioactive particulate emissions occur in a mill in any dry grinding circuit and in the yellowcake drying and packaging process. High-energy venturi scrubbers or bag houses can be used to reduce these emissions. A small amount of radon will also be emitted in the grinding operation and in the leaching circuit. Autogenous or semi-autogenous grinding reduces the emission of radon in this circuit. Emission of radon during milling is low enough that levels outside the plant area due to this emission should not pose any health hazards to the general population.

Fugitive emissions can result from particles from ore piles becoming airborne during gusty winds. Levels of radioactivity in excess of background have been found for several feet below inactive mill's ore piles, indicating migration of the radionuclides downward. Water runoff during rainstorms can transport ore along the ground surface. A mill can be designed with ore pads, ore wind breaks, and ponds to catch rain runoff (Perkins, 1979). Much of New Mexico's ore is mined wet; however, wind transport of ore dust from ore piles has been noted. A radiological assessment of the ore dust is made in the environmental reports for uranium mills. During operation, the radioactivity from ore dust in mills is monitored. Dust control procedures are being required for mill operation (Gerald Stewart, personal communication, August 1980).

A mill also has sanitary wastes, wastes from washing the plant and worker clothes, and shower water. Shower water and water from washdown of the plant, if they contain radioactive contaminants, are sent to the tailings ponds or reused in the mill cycle.

The largest discharge from a mill is the spent process material. Since so little uranium is in the ore, almost everything which goes into the mill is discharged from the mill as tailings. These tailings will contain all the spent chemicals, process water, and the sand-slime mixture which once was ore. At the end of 1979, there were approximately 73 million tons of tailings in New Mexico. If the $50 forward-cost ore reserves cited in Chapter VII are exploited, there will be an additional 482 million tons of tailings (by dry weight) (U.S. Department of Energy, 1980a).

In most New Mexico ores, the uranium is in equilibrium with its daughters. Thus, most of the original radioactivity that was in the ore is also discharged with the tailings. Many of these daughters have low concentration limits in air and water. Since there are several daughters of long halflife in the uranium decay chain, the radionuclides in the tailings will undergo radioactive decay and thus lose toxicity at a very slow rate.

Other toxic materials in the tailings can include trace elements such as selenium, and the organics which were used in solvent extraction.

Movement of tailings contaminants can occur in many ways. Tailings piles can seep and elements contained in the seepage may be mobilized. (Eadie et al., 1976; Purtymun et al., 1977; Ford, Bacon and Davis, Utah Inc., 1977). Elements in solution can be noted from the sampling data given in Tables X-2, X-3, X-4, X-5, and X-6. Excessive levels of selenium have been found in well water near the UN-HP (United Nuclear-Homestake Partners) mill; however, soils in the general area of the tailings also contain selenium. (N.M. Radiation Protection Bureau).

Tailings dams can also erode due to the action of flowing water, and surface runoff can carry tailings into the surrounding area. This is quite evident at the old Phillips pile (Douglas and Hans, 1975; Ford, Bacon and Davis, Utah Inc., 1977).

Table X-2. UN-HP Mill - Sump for Tailings Pond Water Drainage (New Mexico Water Pollution Control Bureau).

	Sampling Date		
	10/26/77	11/16/78	11/06/79
TSS mg/l	32.0	52.0	44.0
TDS mg/l	17035	20710	25400
cond µmhos	20790	23990	28840
pH	10.12		10.32
As mg/l	2.86	7.192	5.020
Ba mg/l	< .100	.051	.100
Se mg/l	51.18	31.160	27.88
Mo mg/l	72.0	105.201	104.5
NH_3 mg/l	11.23	13.9	17.8
Na mg/l	6141.0	8464	9292
Cl mg/l	793.2	1014.1	1418
SO_4 mg/l	5531.6	8346	8411.5
Ca mg/l		10.0	60.0
K mg/l		31.2	35.1
bicarbonate mg/l			2388
Cd mg/l		.0277	.001
nitrate nitrite mg/l		22.42	10.72
Mg mg/l			813.0
V mg/l		13.6	1.18
Zn mg/l		< .100	< .250
Al mg/l			< .250
Pb mg/l		< .005	.007
gross α pCi/l		10000±1000	3400±400
Ra-226 pCi/l	58±4	90±1	56±17
Ra-228 pCi/l	0±2		
Pb-210 pCi/l	49±8		
U mg/l	44.0	52.8	4.17

(Samples unfiltered)

Table X-3. UNC Mill Tailings Pond Water (New Mexico Water Pollution Control Bureau).

	Sampling Date	
	11/13/78[1]	11/01/79[2]
TSS mg/l		435
TDS mg/l		39043
cond µmhos		40788
pH		1.33
As mg/l	1.235	1.870
Ba mg/l	.183	.372
Se mg/l	.0934	.450
Mo mg/l	2.123	1.659
NH_3 mg/l	453.0	3.32
Na mg/l	595.7	549.7
Cl mg/l	320.9	296.8
SO_4 mg/l	1363	28,876
Ca mg/l	513.6	544.0
K mg/l	99.84	82.3
bicarbonate mg/l		
nitrate nitrite mg/l	3.97	2.03
Mg mg/l		1205
V mg/l	39.25	56.630
Zn mg/l	9.37	8.25
Al mg/l		1220
Pb mg/l	.545	.875
Cd mg/l	.0094	.014
gross α pCi/l	62000±3000	43000±2000
Ra-226 pCi/l	88±2	27±8
Ra-228 pCi/l		
Pb-210 pCi/l		
U mg/l	9.39	11.4

1 North pond

2 West Borrow pit decant

(Samples unfiltered)

Table X-4. Anaconda Bluewater Mill - Decant from Tailings (New Mexico Water Pollution Control Bureau).

	Sampling Date		
	10/26/77	11/17/78	11/07/79
TSS mg/l	20.5		52
TDS mg/l	17850		37275
cond µmhos	19635	54285	65714
pH	2.15		.87
As mg/l	.62	3.0645	3.07
Ba mg/l	.55	.187	.241
Se mg/l	.006	.0702	6.966
Mo mg/l	.16	.6936	.955
NH_3 mg/l	56.9	105.25	106.0
Na mg/l	2118.3	1738	1111.0
Cl mg/l	3111.9	2354.3	1251.2
SO_4 mg/l	8521.6	22,792	33,812
Ca mg/l		688.0	320.0
K mg/l		100.62	126.4
bicarbonate mg/l			Acid
Cd mg/l		.0972	.096
nitrate nitrite mg/l		14.11	$<$ .01
Mg mg/l			2101
V mg/l		43.9	48.96
Zn mg/l		12.390	$<$ .250
Al mg/l			1120
Pb mg/l		.0554	1.440
gross α pCi/l		45000±2000	2200±100
Ra-226 pCi/l	1800±100	50±2	15±4
Ra-228 pCi/l	0±2		
Pb-210 pCi/l	1200±100		
U mg/l	53.0	47.62	18.5

(Samples unfiltered)

Table X-5. Kerr-McGee Ambrosia Lake Mill - Decant from Tailings Pond (New Mexico, Water Pollution Control Bureau).

	Sampling Date	
	11/16/78	11/06/79
TSS mg/l		98
TDS mg/l		40002
cond µmhos		45,320
pH		1.33
As mg/l	5.586	2.87
Ba mg/l	.150	.231
Se mg/l	.700	2.788
Mo mg/l	1.429	21.822
NH_3 mg/l	396.0	368
Na mg/l	1759.5	1895
Cl mg/l	2250.2	2199.6
SO_4 mg/l	24,476	29,819
Ca mg/l	432.0	224.0
K mg/l	82.68	97.9
bicarbonate mg/l		acid
Cd mg/l	.0263	.018
nitrate nitrite mg/l	9.03	15.64
Mg mg/l		1777
V mg/l	85.5	106.75
Zn mg/l	7.05	6.910
Al mg/l		1,250
Pb mg/l	.996	1.615
gross α pCi/l	73000±2000	8300±400
Ra-226 pCi/l	160±10	51±15
Ra-228 pCi/l		
Pb-210 pCi/l		
U mg/l	16.2	13.4

(Samples unfiltered)

Table X-6. Sohio Mill - Tailings Pond Liquor (New Mexico, Water Pollution Control Bureau).

		Sampling Date[1]	
	11/15/77	11/27/78	11/08/79
TSS mg/l	371		263
TDS mg/l	32056	46104	39760
cond µmhos	71820	89,376	71523
pH	.96		.98
As mg/l	1.108	1.594	1.110
Ba mg/l		.110	.301
Se mg/l	.33	.065	4.181
Mo mg/l	.679	.332	.310
NH_3 mg/l	507.37	466.0	199.0
Na mg/l	1203	1662.9	926.9
Cl mg/l	529.9	660.5	370.9
SO_4 mg/l	303.8	57824.3	36865
Ca mg/l			352.0
K mg/l		182.13	96.3
bicarbonate mg/l			
Cd mg/l		.050	.019
nitrate nitrite mg/l		6.02	2.22
Mg mg/l			1275
V mg/l		102.0	48.33
Zn mg/l		6.2	5.24
Al mg/l			1,110
Pb mg/l		1.991	2.150
gross α pCi/l		9000±300	31000±2000
Ra-226 pCi/l	180±20	98±1	25±8
Ra-228 pCi/l	38±10		
Pb-210 pCi/l	1800±100		
U mg/l	1.1	23.3	4.23

[1] Sample from decant line sump - unfiltered

Tailings pipes can break. A break in the pipe at the UNC (United Nuclear Corporation) mill deposited tailings on the ground near the tailings pile. When the tailings pipe broke at UN-HP, the break eroded the dike area, causing loss of liquid of the entire cell into the nearby surrounding area. The spill was contained on company-controlled property.

Tailings can also move due to high winds. Sand dunes on the downwind side of tailings piles and levels of radioactivity in excess of background in these areas testify to the effectiveness of this type of transport (Dreesen et al., 1978).

If tailings move into surface water drainages, the water becomes contaminated and the tailings and tailing solution can be carried long distances. When the UNC tailings dam broke in 1979, tailings liquor was transported several miles.Chapter V contains a description of this dam failure (Nucleonics Week, 1980).

Radon gas also diffuses from tailings piles. When radium decays into radon, some of the radon becomes free to diffuse as a gas. If the radon is close enough to the surface so that it does not decay into its non-gaseous daughter before reaching the atmosphere, the radon diffuses out and becomes airborne. Radon will continue to diffuse from a pile unless a suitable cover is placed on the pile so that the radon decays before it reaches the ambient atmosphere (Marple and Clements, 1978; Ford, Bacon and Davis, Utah Inc., 1977; Dames and Moore, 1977).

There have been many measurements made of radon flux from tailings piles (Marple and Clements, 1978; Hans et al., 1978; Clements et al., 1978). These measurements do not give a consistent number. Such factors as atmospheric conditions, Ra-226 content of the waste, moisture content of the waste, any vegetation growing on the waste, size of the waste grains, and measurement technique used all influence the measured emission rate of radon to the atmoshere. Because the numbers measured vary so widely (for example compare - NUREG/CR-1138 Diffusion and Exhalation of Radon from Uranium Tailings with LA-7254-PR, "The Contribution of Radon-222 to the Atmosphere from Inactive Uranium Tailings Piles and Its Attenuation by Cover Materials"), it is difficult to determine an average number to use. Assume, however, a flux of 250 pCi/m^2 sec for the dry areas. Excluding wet areas and partly stabilized piles, this assumption gives a total radon emission of 28,900 Ci per year from New Mexico piles. This number could probably be off by a factor of two. While it does not appear that at the present time mill tailings emit as much radon as do mining activities (see Table X-1), emissions from uncovered mill tailings will continue until the pile undergoes suitable rehabilitation.

If plants grow on mill tailings or if mill tailings move into areas where plants grow, the plants can become contaminated with the radionuclides and other toxic elements contained in the tailings. If animals graze on the plants (animals may also ingest tailings along with the plant), these toxic materials may move into the tissue and/or milk of the animal (Dreesen et al., 1978; Kelley et al., 1978).

Exposure

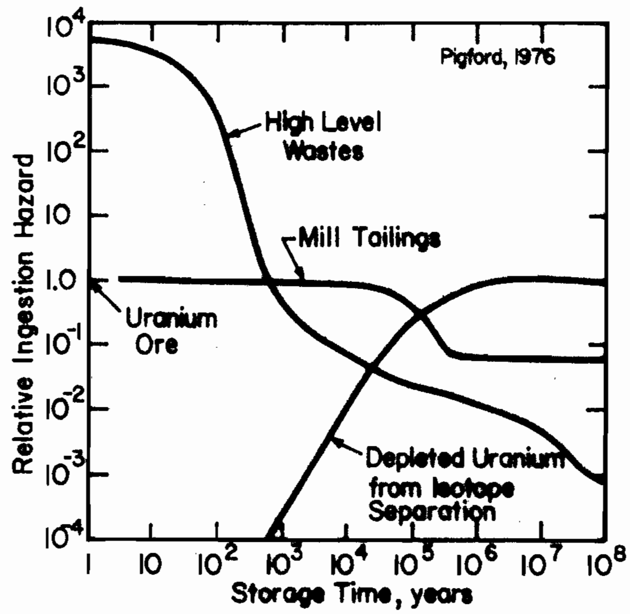
Although it is difficult to predict on the long-term basis how radionuclides and other toxic elements may be transferred to man and while a calculation of an ingestion hazard may be somewhat misleading, it is interesting to compare relative ingestion hazard versus storage time in years of high level wastes, mill tailings, uranium ore, and depleted uranium. Such a calculation has been performed by Pigford and Choi and is shown in Figure X-1. This indicates that after about 600 years the relative ingestion hazard for mill tailings is greater than for high level wastes (Reviews of Modern Physics, 1978).

Assessment-Situation

While a great many studies have been completed in recent years on the environmental effects of the uranium milling process, more studies are needed in order to fully assess the emissions and evaluate all the pathways to man which may increase the general exposure, both to radionuclides and other toxic elements.

Present and possible future emissions due to mining and milling, however, represent some of the most significant emissions in the whole nuclear fuel cycle. Control of dispersion of wastes from mining and milling will reduce future hazards. The state and the federal government, therefore, have been moving toward requiring better disposal techniques for wastes from the new mills undergoing licensing. The problem of stabilization of the wastes of the present mills in operation remains to be solved (EID Radiation Protection Regulations, 1980; EPA, 1980).

Figure X-1. A comparison of relative ingestion hazard versus storage time (in years) of uranium ore, mill tailings, high level wastes, and depleted uranium; (Pigford, 1976).



If the EPA (U.S. Environmental Protection Agency) criterion of clean-up to a level of 5 pCi/gm of Radon-226 is used as a criterion for decontamination throughout the region where mining and milling activities have taken place, preliminary data indicates that an extremely large and very expensive clean-up effort will be required. As mining and milling moves into new regions (Crownpoint and Marquez), tight control on all discharges will be necessary if expensive clean-up is to be minimized in these areas.

Studies

There have been several studies published in the past years on the front end of the nuclear fuel cycle. Some of these are covered in the list of references at the end of this publication.

In the last two years, many measurements and reports have been completed covering emissions and radionuclide transport from milling and yellowcake transportation. For example:

1) Michael H. Momeni, J.B. Lindstrom, C.E. Dungey, and Walter E. Kisieleski, Radon and Radon-Daughter Concentrations in Air in the Vicinity of the Anaconda Uranium Mill, Argonne National Laboratory Argonne, Ill., NUREG/CR-1133, November 1979 - this study gives the results of measuring radon concentration, working level, and meteorological variables near the Anaconda mill and tailings area from June 1977 through June 1978. One meter from the center of the tailings the radon concentration averaged 10 pCi/l and did not begin a significant drop until approximately 100m from the center. Background concentration was essentially obtained at 10km. As expected, concentrations of radon showed diurnal and seasonal variation and dependence on regional air-mass movements.

2) Michael H. Momeni, Walter E. Kisieleski, Donald R. Rayno, and Carmen S. Sabau, Radioisotopic Composition of Yellowcake, An Estimation of Stack Release Rates, Argonne National Laboratory, Argonne, Ill., NUREG/CR-1216, December 1979 - this study reports measurement of concentrations of U-238, U-235, U-234, Th-230, Ra-226, and Pb-210 in yellowcake. The uranium concentrate from Kerr- McGee and Anaconda were two of the four concentrates analyzed.

3) Michael H. Momeni, and Walter E. Kisieleski, Measured Concentrations of Radioactive Particles in Air in the Vicinity of the Anaconda Uranium Mill, Argonne National Laboratory, Argonne, Ill., NUREG/CR-1320, February 1980 - this study measured concentrations of U-238, Th-230, Ra-226 and Pb-210 in air in the vicinity of the Anaconda mill. No measurement indicated levels above the present MPC.

4) Michael H. Momeni, Albin J. Zielen, James E. Miranda, Jr., Norbert D. Kretz, and Walter E. Kisieleski, Systems for Continuous Measurement of Airborne Radon-222 Concentration and Working Level, Argonne National Laboratory, Argonne, Ill., NUREG/CR-1412, April 1980 - this report describes a system developed for continuous and simultaneous measurement of radon and working level in air.

5) W.B. Silker, P.G. Heasler, Diffusion and Exhalation of Radon from Uranium Tailings, Battelle Pacific Northwest Laboratory, Richland, Washington, NUREG/CR-1138, October 1979 - this study used various techniques to measure radon flux at UN-HP's and Kerr-McGee's tailing piles at various locations in each pile.

6) F.F. Haywood, W.A. Goldsmith, P.M. Lantz, W.F. Fox, W.H. Shinpaugh, and H.M. Hubbard, Jr., Assessment of the Radiological Impact of the Inactive Uranium - Mill Tailings at Shiprock, New Mexico, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-5447, December 1979 - this study measured Ra-226 and Th-232 levels in soils, measured gamma levels, did limited water sampling, reported radon daughter measurements, reported measured concentration of airborne radioactive particles and tried to determine possible health effects at the Shiprock tailings pile.

7) F.F. Haywood, D.J. Christian, B.S. Ellis, H.M. Hubbard, Jr., D. Lorenzo, W.H. Shinpaugh, Radiological Survey of the Inactive Uranium - Mill Tailings at Ambrosia Lake, New Mexico, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-5458, June 1980 - this study is similar to the one described above but covers the old Phillip's pile.

8) C.C. Travis, A.P. Watson, S.J. Cotter, M.L. Randolph, D.E. Fields, and L.M. McDowell-Boyer, A Radiological Assessment of Radon-222 Released from Uranium Mills and Other Natural and Technologically Enhanced Sources, Oak Ridge National Laboratory, Oak Ridge, Tenn., NUREG/CR-0573, February 1979. The title of the report describes the study.

9) Gorman S. Hill, Doses for Various Pathways to Man Based on Unit Concentrations of Radionuclides Pertinent to Decontamination and Decommissioning of Properties, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL/OEPA-7, March 1979.

10) C.W. Fort, Jr., R.D. Douglas, R. Gauntt, and A.R. McFarland, Particle Size Distribution of Yellowcake Emissions at the United Nuclear - Churchrock Uranium Mill, U.S. EPA, Office of Radiation Programs, Las Vegas, Nevada, June 1980 - this study measured emissions and particle size from the packaging stack and dryer stack of the Churchrock mill. The dryer stack had an emission of 109±27.1 g U_3O_8/hr (90% respirable) and the packaging stack had an emission of 2.07±.692 g U_3O_8/hr (69% respirable) with the U_3O_8 emission expressed as equivalent U_3O_8.

11) Draft EIS for Remedial Action Standards for Inactive Uranium Processing Sites, U.S. EPA, Office of Radiation Programs, March 1980. This report reviews the results of studies on tailings and provides background for the proposed standards for mill tailings.

12) J.J. Swift, Distant Health Risks from Uranium Mill Tailings Radon, U.S. EPA, Office of Radiation Programs, Technical Note ORP/TAD-80-1, 1980.

13) V.C. Rogers, R.F. Overmyer, K.M. Putzig, C.M. Jensen, K.K. Nielson, and B.W. Sermon, Characterization of Uranium Tailings Cover Materials for Radon Flux Reduction, Argonne National Laboratory and Ford, Bacon, and Davis Utah Inc., NUREG/CR-1081, March 1980. The purpose of this study was to determine diffusion coefficients of radon. Plants with roots in the tailings and moisture content were found to influence diffusion.

14) L.M. McDowell-Boyer, A.P. Watson, and C.C. Travis, Review and Recommendations of Dose Conversion Factors and Environment Transport Parameters for ^{210}Pb and ^{226}Ra, Oak Ridge National Laboratory, Oak Ridge, Tenn., NUREG/CR-0574, March 1979.

15) Anaconda Bluewater Mill Tailings Dam Valencia County New Mexico-Phase I Inspection Report, Tierra Engineering Consultants Inc., August 1979.
Rio Grande Basin Sohio L-Bar Tailings Dam Valencia County New Mexico-Phase I Inspection Report, Tierra Engineering Consultants Inc., August 1979.
Rio Grande Basin United Nuclear - Homestake Partners Tailings Dam-Phase I Inspection Report, Tierra Engineering Consultants Inc., August 1979.
Rio Grande Basin Kerr-McGee Tailings Dam-Phase I Inspection Report, Tierra Engineering Consultants Inc., August 1979

These four reports indicate the results of inspections made on each mill tailings dam. Considerations included diversion of flood waters, faults, monitoring of dam sinking and seepage, chemical reactions, liquifaction, etc. Recommendations were made which are being followed up by the State's regulatory agencies.

16) Status Report on Sampling Program to Determine the Environmental Impact of the United Nuclear Corporation Mill Tailings Spill, New Mexico Health and Environment Department, Environmental Improvement Division, State of New Mexico, November 2, 1979. This is an informal report giving results for soil, water, and air samples collected after the UNC tailings dam break in the summer and fall of 1979 along the Rio Puerco by EID and other sampling groups. This data

indicates that Th-230 and Pb-210 (and perhaps Po-210) are the major radionuclides that were transported from the tailings. Elevated Th levels were especially high in the salts which deposited out along the stream bank. As more data becomes available it will be published - a report should be available in late 1980.

17) David G. Boyer, Dennis McQuillan, and Maxine S. Goad, New Mexico Surface Impoundment Assessment, February 1980, Water Pollution Control Bureau, EID, State of New Mexico, February 1980 - this report includes the UN-HP and Anaconda inactive mill tailings piles, and the milling operations of Anaconda, Kerr-McGee, UNC, and UN-HP as potential sources of groundwater contamination.

18) L.C. Schwendiman, G.A. Sehmel, T.W. Horst, C.W. Thomas, R.W. Perkins, A Field and Modeling Study of Windblown Particles from a Uranium Mill Tailings Pile, Battelle Northwest Laboratory, Richland, Washington, NUREG/CR-0629, April 1979. This report indicates that Ra-226 and Pb-210 levels in soils are above background levels at distances out to 5 miles from the UN-HP active tailings pile. The decay of this dispersed radium accounts for a radon emission of approximately 30% of that from the UN-HP tailings pile itself.

19) J.D. Colton, and R.E. Emerson, A Study of the Mechanics of a Transportation Accident Involving Natural Uranium Concentrate, SRI International, Menlo Park, CA., NUREG/CR-0558, January 1979. This report investigated failure of yellowcake shipping drums and recommended techniques for reducing failure.

20) Draft Generic Environmental Impact Statement on Uranium Milling, NRC, Washington, D.C., NUREG-0511, Vol. I, II, April 1979 - This was a generic study on mill tailings. A summary of impacts released in this report is given in Table X-7.

21) B. Jackson, W. Coleman, C. Murray, and L. Scinto, Environmental Study on Uranium Mills, Part 1, TRW, Redondo Beach, California, February 1979 - this study included results of sampling various inlet and outlet liquid streams at Sohio's mill.

22) Burton J. Thamer, Kirk Nielson, Vern C. Rogers, Robert F. Overmyer, Bradley S. Sermon, and Paul J. Macbeth, Radon Diffusion and Cover Material Effectiveness for Uranium Tailings Stabilization, Ford, Bacon, and Davis Utah Inc., Salt Lake City, Utah, May 1980 - this study reports radon diffusion studies with a variety of possible tailings cover materials under laboratory conditions.

23) Mary Lynn Marple, Radium-226 in Vegetation and Substrates at Inactive Uranium Mill Sites, LASL, Los Alamos, New Mexico, LA-8183-T, January 1980. This thesis reports work done on

determining Ra-226 uptake in plants including leaf surface contamination.

24) Nathan Edmund Kelley, *Vegetational Stabilization of Uranium Spoil Areas, Grants, New Mexico*, LASL, Los Alamos, New Mexico, LA-7624-T, January 1979. This thesis includes re-vegetation of uranium mill tailing piles and the constraints which may effect germination.

25) David Dreesen and Lynn Marple, "Uptake of Trace Elements and Radionuclides from Uranium Mill Tailings by Four-Wing Salt-bush (Atriplex canescens) and Alkali Sacaton (Sporobolus airoides)," *Symposium on Uranium Mill Tailings Management*, Colorado State University, Fort Collins, Colorado, November 19-20, 1979 - This study determined native plant uptake of trace elements including Ra-226, Mo, U, Se, V, and As grown in alkaline tailings. Mo and Se concentrations of the plants grown in the tailings were above levels considered toxic to animals. Ra-226, U and Ni levels were also above MRC.

26) Maxine Goad et al., *Water Quality Data for Discharges From Uranium Mines and Mills in New Mexico*, Water Pollution Control Bureau, EID, State of New Mexico, July 1980. This study gives the results of three years of sampling liquid in mill tailings ponds and decant ponds.

Table X-7. Summary of Integrated Impacts of Conventional Uranium Milling Industry Through the Year 2000[a].

Production (MT U_3O_8 x 1000)	460-740 (690)[b]
Natural Resource Use	
Land Temporarily Disturbed Milling (ha x 1000)	16-25 (24)[c]
Tailings Disposal Land Permanently Committed to Restricted Use (ha x 1000)	4.4-7 (6.4)[c]
Land Temporarily Disturbed Mining (ha x 1000)	4.2-6.6 (6.2)[d]
Water Lost to Evaporation (m^3 x 10^8)	3.9-6.1 (5.8)[d]
Effluents	
Tailings Solids (MT x 10^8)	5.0-7.4 (6.3)[e]
Radon Mills (1978-2000) (Ci x 10^7)	0.7-2.5 (2.0)
Radon Mines (1978-2000) (Ci x 10^7)	0.3-1.2 (1.0)
Persistent Radon Releases from Tailings (KCi/yr)	2.0-5.0 (4.0)
Continental Radiological Impacts	
Milling	
Health effects - 1978 to 3000 (premature deaths)[f]	57-142 (114)
Life Shortening - 1978 to 3000 (years lost)[f]	1080-2700 (2200)
Persistent Health Effects - Beyond 3000 (premature deaths/yr)[g]	0.02-0.05 (0.04)
Milling Occupational	
Health Effects - 1978 to 2000 (premature deaths)	19-30 (28)
Life Shortening - 1978 to 2000 (years lost)	360-570 (530)

Table X-7 (cont'd)

Mining	
Health Effects - 1978 to 2000 (premature deaths)	58-145 (115)
Life Shortening - 1978 to 2000 (years lost)	1100-2750 (2200)

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a The values in parentheses were used throughout the cited document.

b For the basis of these numbers, see Chapter III of this document

c This value is based on the approximate number of model mills (80) needed in the year 2000.

d This value is based on the number of model mill years (880) required to fill 80 percent of future U_3O_8 needs (865,000 MT). The non-conventonal milling industry is expected to fill 20 percent (175,000 MT) of the 865,000 MT required over the time period 1978 to 2000.

e This includes tailings at inactive sites, tailings currently existing at active sites, and future tailings expected to be generated by conventional milling.

f This includes a conservative estimate of the number of health effects (72 premature deaths) during the years 1978-2000 because the effect of covering tailings during operations beyond the base case (40% covered) has not been taken into account. The degree to which radon is controlled during operation of the mill is a speculative matter, depending upon the tailings management practices used

g Estimates of radiological impacts include uncertainties on source term only. The range of radiological impacts does not include uncertainties in environmental transport or in health effects models. Uncertainties in health effects models would extend the above ranges by one-half to two.

Emissions

The quantity of wastes discharged from in-situ projects recovering uranium is usually small compared to uranium mining and milling. The principal wastes are the liquid bleed wastes. During active recovery of the uranium, when chemicals are being added to the injected water and uranium recovered from the liquid coming from the production wells, a small bleed is necessary to maintain a water balance and to prevent buildup of unwanted contaminants in the circulated liquid. This bleed is usually about 1-2 percent (15-30 gpm in a full scale facility) of the total flow. At the present time the only New Mexico facility now in operation is discharging this bleed into a lined evaporation pond (Mobil Oil, personal communication, November 1980). When the leaching operation is over, the aquifer in the region in which the leaching was taking place must be restored. There are two techniques for doing this. The one most commonly used outside of New Mexico is to pump the wells and thus create a flow of aquifer water into the leached area to remove contaminants. This water is then produced from the wells and must be disposed of in some acceptable manner (ie. evaporation, use in milling, deep well injection, etc.). Using this technique, it has been estimated that 20 to 30 times as much water is used during restoration than during the leaching process itself (Cowan et al., September 1980). In New Mexico, Mobil plans to treat the contaminated liquid which flowed through the leached region with a reverse osmosis unit to remove contaminants and to reinject into the same leached region this "clean" fluid. The staff at Mobil expect that even using the reverse osmosis treatment that approximately 20 percent of the production fluid will have to be bled from the system and allowed to evaporate in lined ponds. Reverse osmosis has never been demonstrated to work in this type of application and hence, the Mobil pilot demonstration is being carefully followed by those interested in aquifer restoration techniques. In addition, aquifer resoration has yet to be achieved (Pacific Northwest Laboratory, personal communication, December 1980).

In addition to bleed from the surface facilities, there have also been in areas outside New Mexico some excursions in the leaching zone. Various techniques such as overpumping of the wells are used to try to control these excursions (Cowan et al., September 1980).

Radon is also released from the ion exchange facilities, precipitation tanks, ponds and surge tanks. The amount of radon released is probably dependent upon depth and Ra-226 concentration in the ore body as well as fluid flow rate since the radon is contained initially in the produced fluid. However, Exxon has found that for their ore body the radon-222 contained in the produced fluid averages 0.37 uCi/l with an actual release into the ambient atmosphere of 50-75 percent (Cowan et al., September 1980). The release of other radionuclides into the ambient air is dependent upon treatment techniques. If a dryer is used to dry the uranium, uranium-238 will be released. There are no dryers now in operation at in-situ facilities in New Mexico.

Solid wastes discharged by in-situ facilities include unwanted contaminants that are precipitated out of the produced liquid in surface treatment facilities, spent resins, and other spent treatment units such as filters. The type and amount of solid wastes depend on the type of chemicals used, the ore body, and the recovery process. The solid wastes will contain radioactive material (principally Ra-226) and non-radioactive materials such as calcium carbonate, vanadium, sulfates, and molybdenum. However, molybdenum will be recovered as a by-product at the Mobil in-situ project.

Present Assessment Situation

The major environmental health and safety issues are concerned primarily with various aspects of groundwater restoration. It has been reported that restoration of groundwater back to baseline may be technically impossible because of the physical-chemical changes in the geochemical formation resulting from uranium extraction and ion exchange during leaching on the clays (Cowan et al., September 1980). Adequate demonstration of some liquid cleanup process (such as reverse osmosis) is needed so that large amounts of water do not have to be withdrawn and disposed of during aquifer restoration. Further data should also be available as more projects are developed on the release of radon during liquid treatment and storage.

Possible Exposure Pathways

The main exposure pathway appears to be related to changes in water quality in the aquifer. As more data is obtained on liquid treatment techniques and aquifer restoration, better data should be available in order to determine any possible exposure pathways.

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APPENDIX A

POSSIBLE REGULATORY REQUIREMENTS FOR URANIUM DEVELOPMENT IN NEW MEXICO

Agency and Type of Approval	TYPE OF FACILITY & ACTIVITY: Exploration & Prospecting	Water Well, Artesian Well, Hole Plugging	Mining	Milling	Ion Exchange Operation	Sand Backfilling	Mill Tailing Disposal Area	Heap Leach Facility	In-situ Facility	LAND CATEGORIES: Tribal Land	Allotted Indian Land	Public Domain	Acquired Public Domain	Withdrawn Public Domain	State Land	Private Land	National Forest 1.)FD 2.)A.P.D.
STATE AGENCY																	
I. Health & Environment Department, EID																	
a. Radioactive Materials License				■	■	■	■	■	■	?	?	■	■	■	■	■	■
b. Groundwater Discharge Permit				■	■	■	■	■	■	?	?	■	■	■	■	■	■
c. Air Quality Pre-construction permit				■						?	?	■	■	■	■	■	■
II. Natural Resources Department, Water Resources Division																	
a. Dewatering Permit		■	■							?	?	■	■	■	■	■	■
b. Groundwater Appropriation Application		■								?	?	■	■	■	■	■	■
c. Tailings Dam Construction Permit							■			?	?	■	■	■	■	■	■
III. Energy & Minerals Department, Bureau of Mine Inspection																	
a. Registration of Mine			■							■	■	■	■	■	■	■	■
b. Production reporting			■	■	■			■	■	■	■	■	■		■	■	■
c. Health & Safety Accident Invest.			■	■					■	■	■	■	■		■	■	■
IV. State Land Office																	
a. General Mining Lease	■		■												■		
FEDERAL AGENCY																	
V. Department of Agriculture																	
a. U.S. Forest Service																	
(1) Notice of Intent (Submission to District Ranger)	■																■
(2) Exploration Plan (Submission & Approval)	■																■
(3) Operations Plan (Submission & Approval)			■														■
VI. Department of Interior																	
a. U.S. Geological Survey																	
(1) Exploration Plan (Submission & Approval)	■									■	■						
(2) Mine & Reclamation Plan			■							■	■						
b. Bureau of Land Management												■					
(1) Mining Claim	■		■									■	■				■

APPENDIX B

GLOSSARY

arkose - Feldspar-rich, somewhat coarse grained sandstone derived from a granitic source and considered favorable for the occurrence of uranium.

Abo - arkosic redbeds of early Permian age (280 m.y.) exposed throughout central New Mexico that are hosts for small, low-grade deposits of copper and uranium; related to the Sangre de Cristo Formation of northern New Mexico.

ACFM - average cubic feet per minute, used to define a measure of air volume.

acid leach - metallurgical process for the dissolution of uranium values from ores of low lime content, such as sandstone, by means of an acid solution.

adit - a nearly horizontal entry to a mine driven from the surface.

anticline - a structural fold, the core of which contains the stratigraphically older rocks; it is convex upward with limbs dipping in opposite directions.

alkaline leach - metallurgical process for the dissolution of uranium values from ores of high lime content, such as limestone, by means of an alkaline solution.

anomaly - any excess of natural radioactivity above background levels.

Agua Zarca - basal sandstone and conglomeratic unit of late Triassic age (180 m.y.) in the Nacimiento Mountain area of northern New Mexico; related to the Santa Rosa Sandstone and other basal Chinle units elsewhere in the state.

aquifer - any body of rock that contains sufficient saturated permeable material to conduct, store and yield water in economical quantities to wells and springs.

Baca - redbeds of Eocene age (60 m.y.) exposed in the East Mogollon Slope (Datil) area south of the San Juan Basin that are favorable to the occurrence of uranium; related to the Galisteo, McRae and Cub Mountain formations in other areas of the state.

back - the roof or upper part of any underground mining operation.

backfilling - a reclamation technique which returns spoil (waste) material to the mine cuts or pits.

basin - a structurally depressed, sediment-filled area; may also be a topographically low area in which sediments may accumulate.

blowsand - an accumulation of wind-blown sand; eolian sand.

breeder reactor - a nuclear reactor that produces as well as consumes fissionable uranium and thorium to increase energy conversion by 141-fold over light water reactors.

Brushy Basin - a prominent stratigraphic unit, predominately shale and siltstone, that comprises the upper part of the Morrison Formation of Jurassic age (140 m.y.) in the San Juan Basin area.

Btu - British thermal unit; the amount of heat required to heat 1 pound of water to 1°F.

Burro Canyon - a sandstone unit occurring at the top of the Brushy Basin Shale (Jurassic) (140 m.y.) in the Canjilon area of northern New Mexico and throughout the Chama Embayment of the San Juan Basin; related to the Jackpile sandstone of economic usage.

calcrete - a term, esp. British and Austrialian, that describes a calcium carbonate deposit formed on semi-arid and arid surfaces through capillary action and evaporation; analogous to caliche.

calcareous - said of a substance that contains calcium carbonate.

calcite - the mineral calcium carbonate ($CaCO_3$).

caliche - see calcrete; caliche is the more commonly used term in the U.S.

captive ore - ore produced, shipped and milled by the parent company who owns the mine where it originated; as opposed to tolled ore.

carbonaceous - said of a rock that is rich in organic matter, humates or coaly material.

carnotite - a secondary, potassic uranium-vanadium oxide, yellow in color that is typical of shallow, oxidized environments.

Cenozoic - an era of geologic time from the beginning of the Tertiary period some 70 m.y. ago to the present.

Chinle - redbed sequence of late Triassic age (180 m.y.) in New Mexico and southwestern U.S.; host for large uranium deposits in Utah; favorable for the occurrence of uranium in parts of New Mexico.

Cienequilla Limburgite - dark-colored extrusive volcanic flow rock (Quaternary) occurring southwest of Santa Fe in the La Bajada area of the Santa Fe River; locally mineralized with uranium-bearing minerals.

claim - the portion of mining ground held under federal and local laws by virtue of one location and record. Lode claims in New Mexico are not to exceed 1500 feet in length or 300 feet in width, N.M. Stat. 1953, 63-2-1 through 63-2-25.

coffinite - an important ore of uranium in the Grants Mineral Belt, a black uranium silicate, typical of sandstone deposits of the Grants Mineral Belt.

concentrate - uranium oxide, U_3O_8, after recovery and concentration from ore at the end of the milling process; sometimes called "yellow-cake" because of its color and dense, powdery consistancy.

conglomerate - coarse grained, clastic sedimentary rock composed of pebbles or granules commonly cemented by sandstone or clay matrix.

contact metasomatic - mass change in the mineral components of a rock from contact with an invading magma, esp. used with reference to ore genesis.

Cretaceous - the final period of the Mesozoic era; covered a span of time from 65 to 135 m.y. ago.

cribbing - the construction of cribs or timbers laid at right angles to each other as a roof support or as a support for machinery; the close setting of timbers to support loose ground when shaft sinking.

cross-cut - a horizontal opening driven across the mineral trend or normal to the direction of main workings.

cut-off - the minimum grade (% U_3O_8) and thickness of mineralization (ore) that can be profitably mined.

cuttings - particles of rock produced by abrasive or percussive action of a drill bit, returned from a borehole to the surface by air or drilling mud for analysis.

Cub Mountain - a variegated, heterogenous sequence of thick clastic sedimentary rocks peripheral to Sierra Blanca in south-central New Mexico; thought to be latest upper Cretaceous to Eocene in age and related to the Baca and Galisteo elsewhere.

Dakota - a major transgressive, quartzose sandstone, conglomerate and shale sequence of earliest late Cretaceous age (135 m.y.) that is exposed around the San Juan Basin as well as in other parts of the state; favorable to uranium mineralization locally near Gallup where several mines have been developed in the past.

daughter - any one of the intermediate members of nuclides of the radioactive series, between the parent and the end decay product.

dead-time - a measurable interval of coincident loss following each response to radiation pulses in Geiger counters and crystal detectors when the counter is not sensitive to additional pulses; once dead-time has been determined, observed counts can be corrected to true counts; measured in microseconds.

decline - a mine shaft that is not vertical and is usually along the dip of a bed or vein.

development (drilling) - the phase of drilling that follows exploration drilling to delineate the size, mineral content and configuration of an ore body; - (mining) - the opening of an ore body by shaft sinking or surface excavation.

dilution - the contamination of ore with barren wall rock in stoping; the blending of high- and low-grade ores for milling.

disequilibrium - a radiometric state that exists when a uranium deposit is deficient in uranium-238 through physical and chemical weathering processes that have selectively depleted the parent nuclide while enriching daughters such as thorium-234 or radium-226.

drift - a horizontal passage underground; a drift follows the mineral trend or vein as distinguised from a cross-cut; the angular deviation of a borehole from vertical or its intended course.

Dockum - a stratigraphic group designation used primarily east of the Pecos River and south of the Canadian Escarpment for the uppermost Triassic (180 m.y.) sequence that is stratigraphically and lithologically equivalent to the Chinle.

Dosco miner - a crawler-tracked, 200-hp cutter/loader designed for long wall mining. (see "longwall").

electric log - a plot or strip recording of a borehole to scale obtained by measuring various electrical properties of the geological formations penetrated.

en echelon - parallel physical features that are off-set in either plan or side view like the edges of shingles on a roof.

energy - the ability of a body to perform work either as kinetic, potential, heat, chemical, electrical or nuclear, measured in joules and foot pounds.

Entrada - a prominent cliff-forming sandstone of eolian origin and Jurassic in age (170 m.y.) that lies immediately below the Todilto Limestone across the Grants Mineral Belt; locally mineralized.

Espinaso - a volcanic sequence of welded tuffs and tuff breccias, Oligocene in age (30 m.y.), that overlies the Eocene Galisteo Formation in the La Bajada - Hagan Basin area south and west of Santa Fe.

evaporite - a nonclastic sedimentary rock composed of minerals produced from the evaporation of saline solutions in an arid or semi-arid environment.

exploration drilling - the initial phase of drilling performed in search of basic geological information which will be used to define potential targets in the search for a mineral deposit; exploration drilling, if successful, is followed by development drilling.

feldspathic - said of a sandstone or other clastic sedimentary rock that contains feldspar in quantities less than arkose; feldspathic sandstones are considered favorable hosts for uranium deposits.

fission - natural spontaneous or induced splitting, by particle collision, of a heavy nucleus into a pair of nearly equal fission fragments plus some neutrons; the splitting releases a large quantity of energy which is the basis of current fission reactor technology.

fluvial (fluviatile) - of or pertaining to sedimentary deposits laid by streams in a non-marine depositional environment.

forward-costs - operating and capital costs in current dollars that would be incurred in producing uranium resources; such (past) costs are not included.

fossil fuels - any hydrocarbon deposit that may be used for energy fuel: petroleum, natural gas, and coal.

fusion - the combination or fusion of two light nuclei (such as hydrogen) to form a heavier nucleus, accompanied by the release of a large amount of energy.

Galisteo - a redbed sequence of sandstone, shale and conglomerate, Eocene in age (50 m.y.), that occurs within and around the Galisteo area south of Santa Fe, including the Hgan, Galisteo, and Estancia basins; host for uranium deposits locally and considered favorable elsewhere; stratigraphic and lithologic equivalent of the Baca Formation near Datil and the Cub Mountain near Sierra Blanca.

gamma-log - a strip recording of the intensity of natural radioactivity versus depth obtained when a detection device (scintillometer or Geiger counter) is moved through a borehole.

Geiger counter - (Geiger-Muller) - an instrument that detects gamma radiation emitted by radioactive substances; also called Geiger probe.

geology - the science that deals with the history of the earth as recorded in the rock record; economic geology and mining geology are concerned with the application of geologic principles and data to mining, energy development and industry.

geochemical - of or pertaining to the study of those aspects of geology that involve chemical changes or the distribution of elements and atomic species in the earth.

geophysical - of or pertaining to the study of those aspects of geology that involve the physics of the earth including its structure, composition, and development.

gigawatt - one billion watts.

gneiss - a metamorphic rock, foliated and banded with layers and lenticles of granular and flaky minerals having elongated or prismatic habits.

grade - the relative quantity or percentage of mineral content in ore; tenor.

granite - an igneous, plutonic rock in which quartz constitutes 10 to 50 percent of the components, and in which alkali feldspar predominates over plagioclase feldspar; broadly speaking, any entirely crystalline, quartz-bearing plutonic rock.

grouting - the process of injecting a coarse cement into crevices in underground rock formation especially to stabilize and seal the rock wall of a mine shaft or a borehole.

hard rock - a term used to distinguish material which can be excavated only by blasting, as with igneous and metamorphic rocks, and indurated, tightly cemented sedimentary rocks.

haulage level - an underground passage or level used to transport supplies, waste rock, ore and for the movement of miners to and from the hoisting shaft.

head frame - the steel or timber frame at the top of a mine shaft which carries the sheave or pulley for the hoisting cable, and serves various other purposes.

heap leach - a process used to recover uranium and other leachable minerals from low-grade ore, waste or tailings; the material is laid in beds to a thickness of roughly twenty feet, and is leached with acidic solutions or spent liquor from previous operations; intervals are allowed between applications to permit oxidation to occur, the leachate is collected in tanks where uranium values are recovered through ion-exchange (IX).

hoist - a power driven windlass for raising ore, rock, or other material from a mine and for lowering or raising material.

humate - a salt or ester of humic acid; considered to be an ideal reductant for the precipitation of uranium from solution in the natural environment.

in-situ leaching - the extraction of uranium or other soluble metals in the subsurface by means of slowly percolating or acidic solutions.

isopach - a contour line, on a map, drawn through points of equal thickness of a designated stratigraphic unit.

isotope - one of two or more species of the same chemical element (e.g., uranium-235 and uranium-238).

IX - abbreviation for ion-exchange recovery method.

Jackpile - a stratigraphic term of economic usage designating a sequence of uranium bearing sandstone that occurs throughout the Laguna mining district on the eastern end of the Grants Mineral Belt.

jordisite - an amorphous mineral, molybdenum sulfide (MoS_2), associated with ore bodies within Grants Mineral Belt.

Jurassic - the second period of the Mesozoic era (after the Triassic and before the Cretaceous) beginning about 180 m.y. ago and terminating about 135 m.y. ago; rocks of Jurassic age (Morrison Formation) are the hosts for the most important uranium deposits in New Mexico.

κ-factor - the thermal conductivity of a material expressed in standard units, HW.

Kwhr - abbreviation for a kilowatt-hour of electrical energy.

Kva - abbreviation for kilovolt-ampere, a measurement of electrical energy.

lease - a piece of land leased for mining purposes.

lignitic - containing lignite, a low-rank coal.

longhole - underground borehole or blasthole exceeding 10 feet in depth or length.

longwall - a long mine face of ore usually parallel to bedding or ore trend, sometimes amenable to longwall or mechanical mining.

megawatt - one million watts.

Mesozoic - an era of geologic time from the end of the Paleozoic to the beginning of the Cenozoic.

metamorphic - pertaining to a rock-type, altered in composition through heat and pressure (e.g., gneiss, schist, marble).

mill - to crush, wet grind and treat ore so as to extract uranium (or other metals) as a concentrate or oxide (i.e., yellowcake, uranium concentrate, U_3O_8).

mining district - a section of country designated by name, having described or understood boundaries within which mineral is found and which is worked under rules and regulations prescribed by tradition growing out of early miners' need to self-govern independent of all other authority; useful today for legal descriptions of mining claims and leases, production records and geological reference.

Miocene - an epoch of the late Tertiary period, after the Oligocene and before the Pliocene; 25 million to 11 m.y. ago.

molybdenum - a slivery white metallic element of the chromium group, abbreviated Mo; after extracted as a by-product of uranium milling.

Morrison Formation - major uranium-bearing sandstone, siltstone, conglomerate, and shale unit of late Jurassic age (140 m.y.) that occurs throughout the southwestern U.S. especially in the San Juan Basin of New Mexico; it consists of four principle stratigraphic members, some locally absent, in ascending order: Salt Wash Sandstone Mbr; Recapture Shale Mbr; Westwater Canyon Sandstone Mbr; and Brushy Basin Shale Mbr; locally each member may be further sub-divided into units of stratigraphic or economic significance (e.g., Jackpile sandstone, Poison Canyon sandstone).

muck - rock or ore broken in the process of mining.

nuclear fuel cycle - the sequence of processes involved in rendering uranium suitable as a source of energy from the mining and milling conversion (to UF_6), enrichment, fabrication, fission, reprocessing and waste disposal.

nuclear reaction - a reaction involving the nucleus of the atom such as fission, radioactive decay, or fusion; and distinct from a chemical or "atomic" reaction which is limited to changes in electron configuration surrounding the nucleus.

Ogalalla - sandstone, conglomerate and caliche-bearing stratigraphic unit of late Tertiary age (Pliocent-Pleistocene) that caps the high plains or Llano Estacado of southeastern New Mexico, locally present in northeastern New Mexico.

Oligocene - an epoch of the early Tertiary period, after Eocene and before the Miocene, 40 m.y. to 25 m.y. ago.

open-stope method - stoping in which no regular, artificial method of support is employed, although props or cribs may be used if necessary; usually confined to small ore pods where all mineralized material is removed leaving no pillars.

ore - mineralized rock of sufficient grade and quantity to be mined at a profit.

ore roll - a uranium ore body within sedimentary rock (sandstone) that is discordant, forming an S-shaped or C-shaped cross section, usually occurring along the interface of an oxidation-reduction (redox) boundary; when several ore rolls are aligned in plan view, the trend is termed a roll-front; in New Mexico, massive ore rolls occur at Nose Rock northeast of Crownpoint.

Paleozoic - an era of geologic time from the end of the Precambrian to the beginning of the Mesozoic; about 550 m.y. to 200 m.y. ago.

pegmatite - coarse grained, igneous vein or dike rock of granitic composition, rich in rare elements such as lithium, boron, fluorine, uranium, and the rare earths.

Pennsylvanian - a period of geologic time in the late Paleozoic era after the Mississippian and before the Permian thought to have covered the span of time between 320 and 280 m.y. ago.

permeability - the capacity of porous rock for transmitting fluids.

Permian - the last period of the Paleozoic era of geologic time after the Pennsylvanian and before the Triassic, thought to have covered the span of time between 280 and 225 m.y. ago.

pH - a measure of the acidity or alkalinity of water and other aqueous solutions.

physiographic province - a region, all parts of which are similar and distinct in geologic structure, history, and climate, and which has consequently had a unified geomorphic history.

pitchblende - a massive variety of uraninite or uranium oxide found in metallic veins, usually containing a slight amount of radium.

Pliocene - the latest of the epoch comprising and Tertiary period of Cenozoic time after the Miocene and before the Pleistocene, 11 m.y. to about 2 m.y. ago.

plutonic - pertaining to igneous rock formed at great depth such as granite.

plutonium - a radioactive isotope of uranium (mass number 239, half-life, 24,360 years) by spontaneous emission of an electron from neptunium obtained in turn from uranium 238.

Poison Canyon - a stratigraphic term of strictly economic usage that occurs along a zone of intertonguing between the Westwater and the overlying Brush Basin; important sandstone host for uranium deposits in the Smith Lake (Blackjack) and south Ambrosia Lake districts of the Grants Mineral Belt.

porosity - the property of a rock containing voids or interstices that are capable of holding but not necessarily transmitting fluids.

potential resources - the quantities of uranium estimated to be present in deposits that are as yet incompletely defined or undiscovered; they are divided into probable, possible, and speculative classes based on their spatial relationships to defined resources; as opposed to reserves which are defined by direct measurement.

Precambrian - all geologic time before the Cambrian or earliest period of the Paleozoic, ranging from more than 4.5 billion years ago to about 550 million years ago; all rocks formed during the Precambrian.

push-back - a unit of mineralized rock in a strip mining or open-pit operation of sufficient grade, thickness and lateral extent to be stripped or "pushed-back" (extracted) at a profit.

quad - a unit of energy equivalent to a quadrillion (10^{15}) Btu.

quartz - an important and common rock forming mineral, SiO_2, the major constituent of sandstone.

Quaternary - the second period of the Cenozoic era following the Tertiary, consisting of two epochs, the Pleistocene and the Holocene or Recent; ranges in age from two to three m.y. ago.

rad - a unit of absorbed dose of ionizing radiation equal to an energy of 100 ergs per gram of irradiated material.

radium - A radioactive metallic element, silvery-white, resembling barium chemically, and occurring in carnotite, pitchblende and other uranium minerals; abbreviated Ra.

radon - a heavy, radioactive gaseous element formed from the disintegration of radium; abbreviated Rn.

range - any series of contiguous townships of the U.S. Public Land Survey system situated north and south of each other and numbered consecutively east and west from a principal meridan; abbreviated R.

raise - a vertical or inclined opening driven upward to connect two or more levels within a mine.

Recapture - a member of the Jurassic Morrison Formation, largely sandstone, siltstone and shale, that overlies the Salt Wash Member and is subjacent to the Westwater Canyon Sandstone Member; the Recapture is host for uranium deposits in the Sanostee area of northwest New Mexico.

rem - the quantity of ionizing radiation dosage imparted to a biological system per gram of living matter equivalent to a dose of one rad of X-radiation.

resistivity - the opposite of conductivity of an electrical current passing through fluid-bearing rock formations during electrical logging of a borehole expressed in ohm/centimeter.

roof - the ceiling of any underground mine workings; same as "back".

roof-bolt - a long steel bolt driven into the roof of underground excavations to strenghthen the pinning of rock strata.

room-and-pillar - a method of underground mining that leaves pillars of low-grade ore or rock to support the roof or back of workings at regular or irregular intervals between mined areas or "rooms".

royalty - the amount by the lessee, or operator, to the owner of land, mineral rights or mine equipment, based on a set amount per ton or a percent of total production.

Salt Wash - the lowermost member of the Jurassic Morrison Formation; largely sandstone, and an important uranium host rock in the East Carrizo Mountain area of northwest New Mexico. Does not extend south to the Grants Mineral Belt.

sand fill - hydraulic or pneumatic backfill to support underground cavities left by extraction of ore (see "backfilling").

Sangre de Cristo - an arkosic formation of late Pennsylvanian and early Permian age (280 m.y.) tha crops out along the eastern slope of the Sangre de Cristo Mountains between Las Vegas and Guadalupita; considered to be a favorable host for potential resources.

Santa Fe - a complex sequence of basin-fill sedimentary and associated volcanic rocks deposited in the Rio Grande Trough of northern and central New Mexico; late Cenozoic age (Pliocene-Pleistocene); host for small, sparse uranium deposits and many anomalies.

Santa Rosa - a basal sandstone and conglomerate unit of the Chinle (Dockum) in eastern New Mexico and along the Pecos River; late Triassic in age (180 m.y.); considered to be a favorable uranium host rock.

scintillometer - a more sensitive radiation detection instrument than Geiger counters; can distinguish between types of radiation and can be used in aerial geophysical prospecting.

section - a piece of land that is 1 square mile or 640 acres in area forming one of the 36 subdivisions of a township in the U.S. Public Land Survey; abbreviated sec.

secular equilibrium - long-term radioactive equilibrium of naturally occurring radioactive elements (see "disequilibrium").

sedimentary - of or pertaining to rocks formed by the accumulation of sediment in water or air (aqueous or eolian), including evaporites; sandstone uranium deposits are the most important type in the U.S.

self-potential (spontaneous potential) - electrical potential caused by dissimilar conductors (rock types) in an electrolyte (borehole fluid) used in borehole logging and geophysical prospecting; abbreviated SP.

set - a timber or steel support frame used in underground mine workings.

shaft collar - supporting framework at top shaft from which linings may be hung. The term applies to the timber, steel, or concrete around the mouth or top of a shaft.

shale - a laminated, sedimentary rock in which the constituent particles are largely clay size.

sill - the floor of an opening or passage in a mine.

skip - a guided steel hoppit usually rectangular with a capacity from four to ten tons, used in vertical or inclined shafts for hoising ore.

slab - cleaved of finely parallel jointed rocks which split into tabular plates from one to four inches thick.

slab-down - close timbering between sets of timber.

slusher - a machine used for loading ore or rock by pulling an open-bottomed scoop back and forth between the face and the loading point by means of ropes, sheaves, and a multiple drum hoist.

soft-rock - rock that can be removed by air-operated hammers, but cannot be handled economically by a pick; loosely used to distinguish sedimentary from igneous and metamorphic rocks.

square set - a method of stoping in which the walls and back of the excavation are supported by regular framed timbers froming a skeleton enclosing a series of connected, hollow, rectangular prisms in the space formerly occupied by the the excavated ore and providing continuous lines of support in three directions at right angles to each other. The ore is excavated in small, rectangular blocks just large enough to provide room for standing a set of timber.

stacked ore - uranium ore that has been redistributed along faults or vertical fractures, discordant to bedding; a term used almost exclusively in the Grants Mineral Belt of New Mexico.

stope - commonly applied to the extracton of ore, but does not include the ore removed in sinking shafts and in driving levels, drifts and other development openings.

stull - a timber prop set between the walls of a stope.

syncline - a fold in rocks in which the strata dip inward from both sides toward the axis.

tabular ore - a uranium ore body that is concordant to bedding.

tails assay - minimum acceptable percentage of uranium-235 remaining after UF_6 gaseous diffusion to enrich uranium from 0.7 percent U-235 to 3.0 percent U-235; tails assay currently ranges from 0.20 percent to 0.25 percent U-235.

tailing(s) - fine sand fraction remaing after the milling of uranium ore.

Tertiary - the earlier of the two geologic periods comprising the Cenozoic era; began approximately 70 m.y. ago and terminated about 2 to 3 m.y. ago.

thorium - a radioactive, silvery-white, mettalic element, abbreviated Th; is fissionable and can be used as a nuclear fuel.

Todilto - a prominent limestone formation of Jurassic age that is a host for uranium deposits in the Grants Mineral Belt; overlies the Entrada Sandstone and is subjacent to the Summerville Formation.

toll ore - ore that is shipped for milling by an operator other than the mine operator, thus, a toll or surcharge is applied that would otherwise be avoided if the mine and mill operator were the same.

township - a piece of land bounded on the east and west by meridians 6 miles apart at its south border, has a north-sout length of 6 miles, and forms one of the chief divisions of a U.S. Public Land Survey; abbreviated T.

Triassic - the earliest of the three periods comprising the Mesozoic era of geologic time, preceding the Jurrasic and following the Permian.

tuffaceous - said of sediments containing up to 50 percent volcanic tuff, considered favorable as a source of uranium.

U_3O_8 - abbreviation for uranium concentrate (uranium oxide); "yellowcake".

unconformity - an erosional gap or hiatus in the geologic record; important for the localization of some types of uranium deposits.

uplift - structurally high areas of the earth's crust produced by positive movements that raise or upthrust rocks.

uranium - a silvery-white, radioactive metallic element, the heaviest naturally occurring element, abbreviated U; fissionable and used to produce large quantities of heat in nuclear reactors; New Mexico is the number one producer of uranium in the U.S., and is a major producer among leading uranium producing nations.

uraninite - a black, oxide of uranium (UO_2), one of the important ores of uranium.

vanadium - a gray or white, malleable, ductile metallic element, abbreviated V, that occurs in combination with uraninite, carnotite and other uranium bearing minerals.

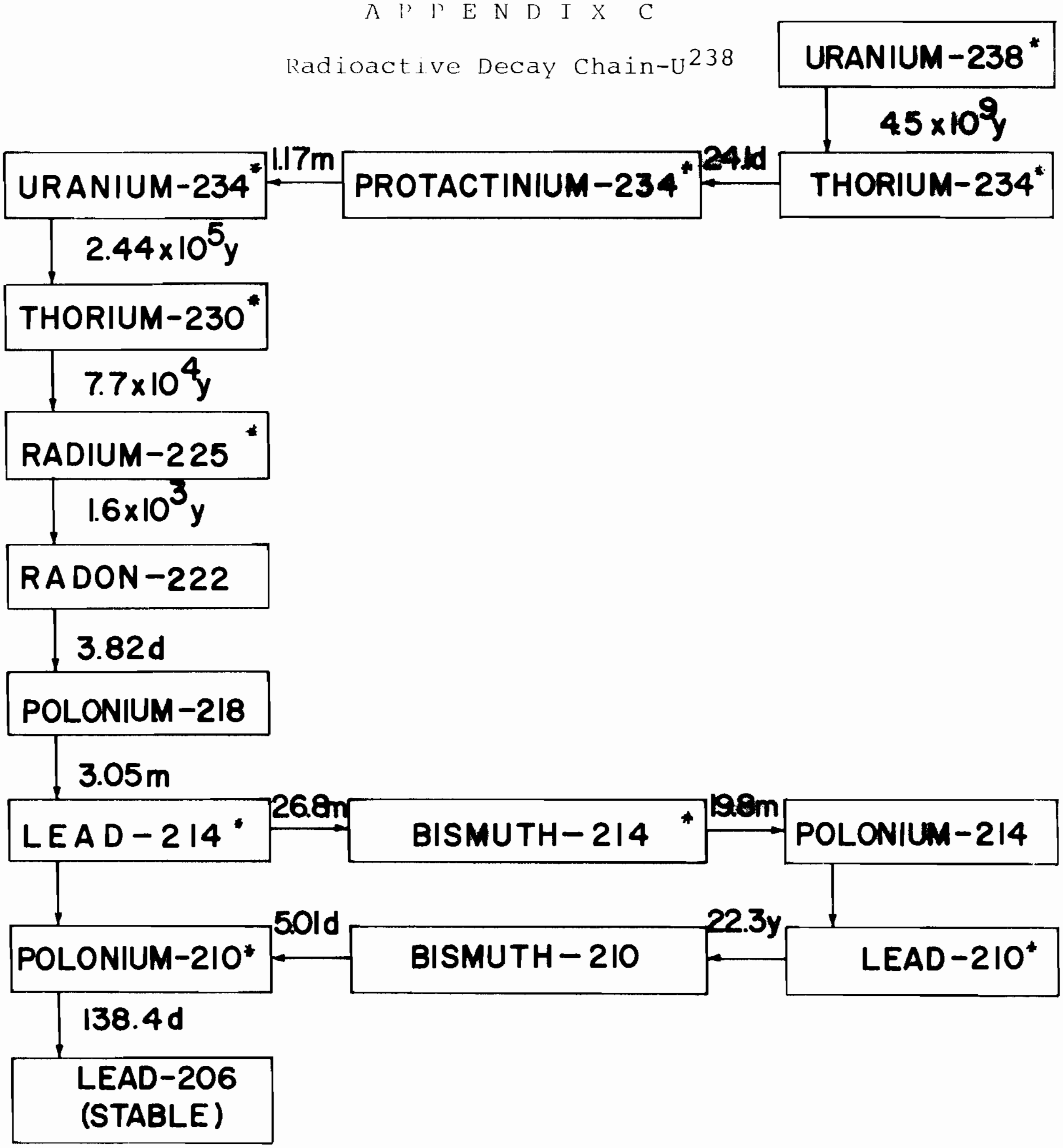
water factor - a compensatory factor that is critical in calculating true gamma-ray detection through water in a uranium borehole; the shielding effect of water to radiation in the borehole.

Westwater Canyon - the principal uranium bearing sandstone member of the Jurassic Morrison Formation in the Grants Mineral Belt; overlies the Recapture Shale Member and is subjacent to the Brush Basin Shale Member.

wildcat drilling - the drilling of exploratory boreholes in unproven territory.

APPENDIX C

Radioactive Decay Chain-U^{238}



NOTE:
VERTICAL DIRECTION REPRESENTS ALPHA DECAY. HORIZONTAL DIRECTION INDICATES BETA DECAY. TIMES SHOWN ARE HALF LIVES. ONLY THE DOMINANT DECAY MODE IS SHOWN.

* ALSO GAMMA EMITTERS

APPENDIX D

Nuclear Fuel Cycle